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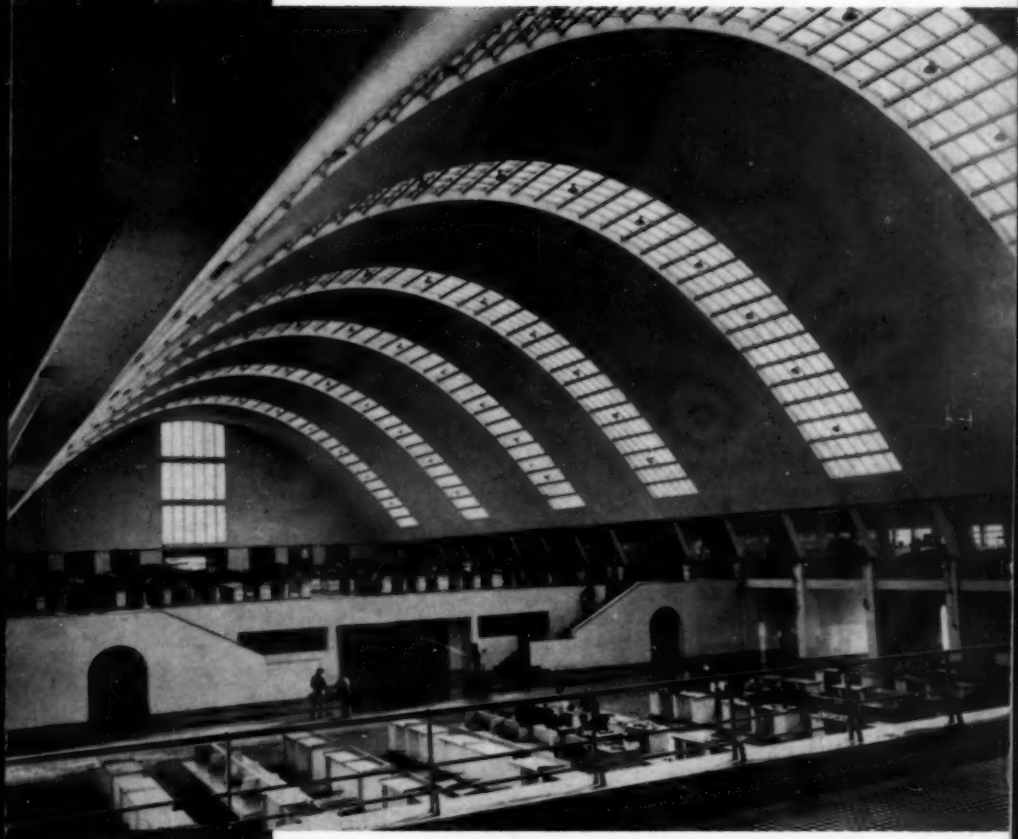

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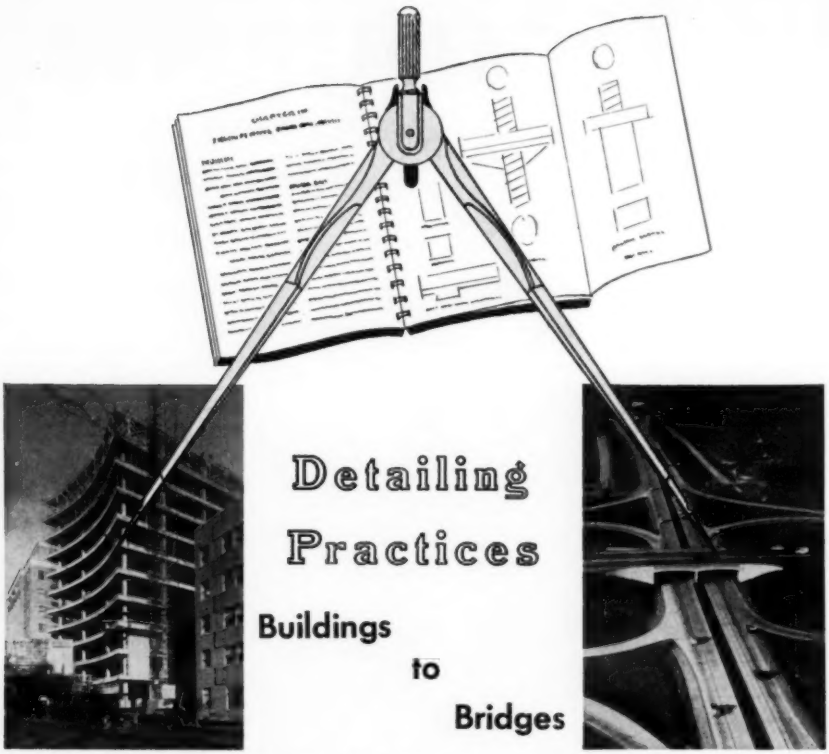

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"Effect of Differential Shrinkage in Composite Beams" is discussed by HALVARD W. BIRKELAND. The author presents a method of analysis for the problem of shrinkage in composite construction.

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Stressing the esthetic qualities of concrete, J. A. HANSON describes the varied applications of "Plastic Forms for Architectural Concrete." He pictures complex designs, bold and shadow patterns, and wide range of textures obtainable with plastic forms.

•

Delving into a field where little test data exists, ALBERT C. BIANCHINI, ROBERT E. WOODS, and CLYDE E. KESLER report on the "Effect of Floor Concrete Strength on Column Strength."

•

"Performance and Design of Special Purpose Blast Resistant Structures," by ROBERT A. WILLIAMSON, describes two structures housing scientific equipment used in nuclear tests in the South Pacific. The report covers general procedure currently used in the design of these structures.

On the Cover—Municipal market in Matosinhos-Leixoes, Portugal. Utilizing a modular coordinated plan, the structure consists of a large nave, about 80 x 40 sq m, and appurtenant rooms. The roof is a parabolic 7 cm thick concrete shell, spanning 38 m with a rise of 11 m. Loads are transmitted to foundation through batter pillars, along the tangent to the curve. Glazing in skylights rests on precast concrete framing. Contractor was Luiz Jose de Oliveira; state supervision was by the Town Planning Department of the Ministry of Public Works. Structural and general design was by Organizacoes ARS; architects were Cunha Leao, Morais Soares, and Fortunato Cabral.—Photo courtesy Laboratorio Nacional de Engenharia Civil, Lisbon, Portugal

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Title No. 56-49

Consolidation of Concrete

Reported by ACI COMMITTEE 609

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The first chapter reviews briefly the history of consolidation of concrete. This is followed by a discussion on advantages of vibration, types of equipment and operating frequencies, forms, and concrete mixes (structural, mass, pavement, floor, lightweight, heavyweight).

The second chapter is devoted to recommended practices and gives information on amount of vibration, effect on entrained air, over-vibration, revibration, and use of retarders. Recommended techniques are outlined for structural concrete, slabs, mass concrete, pavement, (thick, thin, and reinforced), earth-moist concrete, lightweight concrete, heavyweight concrete, concrete block, and precast products.

CHAPTER 1—INTRODUCTION

101—Historical

Since publication of the first recommended practice in the Mar.-Apr. 1936 ACI JOURNAL,[1] techniques and equipment for consolidating concrete have changed radically, and many new concepts have been introduced. Probably the most important development since then has been the use of purposely entrained air. Nevertheless, the committee has found that much of the information in the 1936 report is still valid, and this report on recommended practices applies to non-air-entrained concrete as well as to air-entrained concrete. Much of the following information is extracted from Meissner's paper in the June 1953 ACI JOURNAL.[2]

When concrete was first adopted by the construction industry, the practice was to place it in relatively shallow lifts, or layers, with a con-

sistency resembling that of moist earth. It was compacted with heavy tampers and rammed at the expense of much hand labor. As plain concrete it first found use in foundations, retaining walls, dams, and other structures with sizable dimensions. Those structures of this early period which remain attest that such methods produced concrete of excellent and lasting quality. The use of these very dry, nonplastic mixes is again coming in favor, and a portion of this report is devoted to the subject of consolidation of earth-moist mixes. The term "earth-moist" was agreed upon by the committee as the most descriptive term to identify concrete mixes that are barely moist, and containing considerably less water than concrete having a slump approaching zero.

With the introduction of reinforced concrete came thinner sections and the need for concrete of plastic consistency. The original, earth-moist mixes were too difficult to place in narrow forms containing reinforcing steel, and wet mixes of plastic consistency therefore became the vogue. Since the more workable mixes required less labor, the change was a popular one, and when it was discovered that the new mixes could be transported by inclined chutes, they were made even wetter.

Even among the builders who tamped the early earth-moist concrete, there was recognition of the fact that the drier their mix, the stronger it became. *Bulletin* No. 1, Structural Material Research Laboratory, Lewis Institute, by Duff A. Abrams, showed how the same rule applied to the popular plastic mixes. As knowledge of the fundamental principles of concrete making grew, the undesirable qualities of sloppy mixes became more apparent. Nevertheless, low-slump, dry mixes, which tests had proved would produce better concrete, were not completely favored because of the extra effort and expense required to consolidate them thoroughly.

Then it was discovered that fresh concrete, even though dry and harsh, acquired entirely different rheological properties when shaken or subjected to high frequency vibratory impulses. When converted to a tremulous state, harsh concrete became plastic and plastic concrete became semifluid. Friction between various particles in the mix was reduced by the rapid vibrations to such an extent that the whole mass became more fluid. Under violent agitation, and in the quasiliquid state, the force of gravity caused the mix to subside and seek its greatest density. When the vibrations stopped, friction again immobilized the concrete.

With this discovery, an economical way for consolidating unmanageable, stiff, dry concrete presented itself. Machines for imparting the quivering motion to concrete were developed, and reluctance to use anything but the sloppy mixes began to disappear. With the introduction of the vibrator, it was also found that much handwork could be avoided and that concrete operations were more mechanized, with attendant reduction in cost.

102—Advantages of vibration

The advantages of consolidating concrete by vibration include: lowered cost of concrete through ease of placement and by reduced cement content; greater density and homogeneity in the concrete; greater strength; improved bond with reinforcement; greater bond at construction joints; greater durability; and reduced volume change or shrinkage. These advantages have been so well documented that they require no elaboration here. The savings achieved and improved qualities in concrete are now so well established that vibration has become an accepted practice in practically all types of concrete work. That so many improvements can be attributed to one innovation makes vibration one of the greatest advancements in concrete technology.

103—Consolidating equipment

Consolidating equipment may be divided into five general categories, each type designed to accomplish a specific purpose:

(a) Immersion vibrators, to be immersed directly in the concrete
(b) Form vibrators, to be attached to the forms or molds
(c) Vibrating screeds or pans, to be applied to the surface of concrete
(d) Surface tampers
(e) Miscellaneous tampers and shakers

Fig. 1-8 illustrate common examples of several types. Table 1 provides a summary of information relative to all types of vibrators.

It was early recognized that the effectiveness of vibrators was closely related to the frequency at which they operated. When vibration was first introduced, results obtained with vibrators operating at frequencies of a few thousand cycles per minute were considered astounding. It was soon observed, however, that by increasing the frequency of the vibrator its effectiveness, as judged by the time required to consolidate a given amount of concrete, was increased in even greater proportion. Acceleration of the vibrator was found to be of great importance when judging its efficiency. Since, in simple harmonic motion, acceleration is directly proportional to amplitude but proportional to the square of the frequency, it may be readily appreciated why the enhanced effectiveness of vibrators was noticed when they were speeded up. However, difficulties in producing machines that will endure and give good service

Fig. 1—Flexible shaft, electric vibrator for use in normal structural concrete

TABLE 1—CHARACTERISTICS AND APPLICATIONS OF CONCRETE VIBRATORS

Type*	Recommended minimum frequency, rpm†	Vibrating element, in.		Consolidation capacity, cu yd per hr	No. men to operate	Application
		Length	Diameter			
Immersion spud, hand operated	9000	Up to 13½	½ to 1¾	2 to 5	1	Plastic, workable concrete in very thin members and confined places, and for fabrication of laboratory test specimens. Suitable as an auxiliary to larger vibrators in prestressed work, where many cables and ducts cause congestion in the forms.
Immersion spud, hand operated	9000	10 to 20	1¾ to 2½	5 to 20	1	Plastic, workable concrete in thin walls, columns, beams, precast piles, light floors and roofs, light bridge decks, and along construction joints.
Immersion spud, hand operated	7000	10 to 28	2¾ to 3	15 to 25	1	Plastic, workable concrete with less than 3-in. slump in general construction such as walls, columns, beams, precast piles, heavy floor, bridge deck and roof slabs. Auxiliary vibration adjacent to forms of mass concrete and pavements.
Immersion spud, gang mounted	7000	10 to 28	2¾ to 3		0 to 1	Gang vibrators for pavements may be attached to a frame on the rear of the spreader, on a separate carriage, or on a frame ahead of the first screed of the finisher.
Immersion spud, hand operated	7000	12 to 18	3½ to 4½	25 to 35	1	Mass and structural concrete of 0 to 2-in. slump deposited in increments up to 2 cu yd in heavy construction in relatively open forms, in power houses, heavy bridge piers and foundations, and for auxiliary vibration in dam construction near forms and around embedded items and reinforcing steel.
Immersion spud, hand operated	6000	8 to 19	5½ to 6¾	25 to 50	2	Mass concrete containing 6-in. aggregate deposited in increments up to 8 cu yd, in gravity dams, large piers, massive walls, etc. Two or more vibrators will be required to operate simultaneously to melt down and consolidate increments of concrete of 4 cu yd or greater volume deposited at one time in the form.‡

while operating at high speeds impose practical upper limits on the frequencies to be employed.

The speed of induction-type electric motors is dependent on the frequency of the alternating current and cannot exceed 3600 rpm with 60-cycle current unless this is increased with frequency converters. Converters are now commonly available to produce 180-cycle current, permitting a synchronous speed of 10,800 rpm. The speed of universal-type motors is, of course, limited by their endurance and the load applied to them. When the universal type is employed, power is generally transmit-

TABLE 1 (Cont.)—CHARACTERISTICS AND APPLICATIONS OF CONCRETE VIBRATORS

Type*	Recommended minimum frequency, rpm†	Vibrating element, in.		Consolidation capacity, cu yd per hr	No. men to operate	Application
		Length	Diameter			
Immersion tube, paving machine attachment	5000	Up to 25 ft§	3	—	0	Paving concrete to full depth of slab, depending on number of units, depth of immersion, etc.
Surface, pan or screed	3000	Up to 40 ft long and 18 in. wide	—	—	0 to 2	Surfaces of highway and airport pavement. Slabs less than 12 in. thick. Surface of mass concrete to embed cobbles and to compact horizontal surface. Effective to a maximum depth of about 12 in.**
Surface, rotating disc	1800	—	—	—	1	Wearing surface of less than 2-in. slump concrete in heavy floors, ramps, platforms, bridge decks and roof slabs. Also used to vibrate wearing surface of concrete to integrate either metallic or natural graded aggregate surface hardeners therein.
External, clamped or chained to form††	3600	—	—		—	Concrete products such as pipe, grave vaults, masonry units, forms in products plants, vibrating tables, etc. Used frequently to apply vibration to areas inaccessible to internal vibration in general construction such as tunnel lining, or congested forms such as for prestressed members; also for vibration-consolidation of coarse aggregate prior to grouting in the prepacked method of making concrete.

*Immersion spud vibrators may be either flexible shaft driven or of the motor-in-head type. Flexible shaft drive may be either air or electric motor, or gasoline engine. Motor-in-head types are electrically or pneumatically operated.

†The committee recommends that, for clarity, the speed be shown in rpm rather than in cycles, vibrations, or other units that may be confusing. These values refer to speed when the vibrator is immersed in concrete.

‡Some use is made of gang mountings of large vibrators for consolidating mass concrete.

§The vibratory paving tube may consist of as many as five separate units, covering a width of slab of 25 ft.

**For pavement the surface vibrator is attached to the spreader or finisher. If the pavement is reinforced, it is attached to the spreader or finisher being operated on the top course.

††Vibrators for the external application of vibration vary from less than 25 lb to over 200 lb in weight. The lighter vibrators are, in general, suitable for use on forms of small mass such as those for burial vaults and pipe up to approximately 36-in. diameter. The largest ones might be appropriately used on masonry block machines. Batteries of these vibrators might be required according to the nature of the work requiring treatment, for example, a long prestressed bridge girder.

ted to the vibrator by a flexible shaft (Fig. 1). The maintenance of such shafts, whose life and resistance to wear is a function of the rotational speed to which they are subjected, will generally dictate operational speeds below 10,000 rpm. Motor-in-head vibrators eliminate some of the limitations of flexible shaft machines.

Gasoline engine-driven vibrators also use the flexible shaft for power transmission, with belt and pulley gearing between motor and shaft to keep motor speeds within practical limits. Again, however, safe upper

frequencies that can be employed are governed by what the flexible shaft will endure without excessive repair and replacements.

Pneumatic or hydraulic vibrators, using turbine motors, should be capable of producing very high frequencies, limited only by friction of moving parts and wear and tear of bearings. As a practical matter, their speeds and efficiency depend on a steady and adequate supply of air or fluid at required pressures.

Compressed-air vibrators occasionally give trouble, especially in cooler weather, by freezing at the exhaust unless alcohol is trickled into the air line, or dry air is used. Glycol type antifreeze agents tend to cause gumming of the vibrator valves.

104—Forms

Aspects of form strength and design will be covered in suitable detail in the forthcoming report of ACI Committee 622, Formwork for Concrete. Architectural aspects should be taken care of in job specifications, but it is, of course, essential that vibrating operations be so conducted that there is no damage to form surfaces, which will be reflected in unsightly scars on the concrete surface.

For whatever character of form surface desired, the forms should be mortar-tight. When vibration momentarily turns concrete mortar to a fluid consistency, hydrostatic pressure will cause considerable quantities to flow and if there are holes or cracks in the sheathing the mortar will be lost. When this happens, loss of material may be so great as to cause rock pockets or gravel streaks along cracks, impairing the appearance and perhaps weakening the structure. The degree to which such results are acceptable varies with the character of the work. By the same token the amount of mortar leakage, or crack width between sheathing boards, that is permissible will depend on the desired final appearance of the work. In any case, a considerable leakage of mortar is undesirable and therefore openings greater than 1/16 in. between boards should be prohibited. Even narrower cracks may be objectionable from the standpoint of their effect on appearance of certain surfaces. With only a little experimenting these limits can be readily determined for given job conditions and appearance requirements.

Paving forms should be designed and constructed to maintain line and grade while being subjected to the intense action of the vibrators, at the same time supporting several tons of spreading and finishing machinery.

105—Mixes

Proportioning of concrete mixes is covered in the reports of ACI Committee 613.[3] From the standpoint of vibration, therefore, one is concerned primarily with such aspects of the mix as minimum practical slump and sand content, largest practical maximum size of aggregate, and the amount of beneficial entrained air removed during vibration.

Slump, sand content, maximum aggregate size, and grading of the aggregates are the significant factors affecting the efficiency of a concrete mix, and are the aspects of a mix which create workability. Obviously, workability is essential, but it should never be more than is required for proper consolidation by a modern vibrator fully and properly utilized. Such excess workability is inefficient, and the mix should be adjusted for the sake of economy and better quality.

(a) *Structural concrete*—A 3-in. maximum slump is ample for properly vibrated structural concrete in forms. What may be regarded as a need for wetter concrete in many quarters is better satisfied by more thorough vibration; not only is superior workmanship in placing better assured with more vibration, but the quality of concrete can be improved because the water content can be lowered with less slump. Actually concrete for heavy structural members and slabs can be satisfactorily placed at a 2-in. maximum slump when effectively vibrated. The opportunity to obtain concrete of superior quality, and possibilities for mix economy, can be lost if modern vibration equipment is not fully utilized to place concrete of these lower slumps.

Because a surplus of sand in the mix will provide unneeded workability and increase water requirements, the practical minimum amount of sand should be used in all concrete mixes.

As the maximum size of coarse aggregate is increased, the amount of sand required for essential workability will decrease. Less sand means less water and cement at the same water-cement ratio. For this reason, it is desirable to use the largest practicable maximum size of aggregate in any concrete.

As a result of vibration, concrete containing aggregate of suitable size will flow from the mix and close around the reinforcing bars, despite their spacing or form clearance, without impairment of the quality of the concrete that goes around the bars or of the adjacent concrete from which it came.

Mixes having small maximum size aggregate, excess sand, and moderately high slump will of course be more easily placed because they have considerable surplus workability. Such concretes are popular with workmen and, unfortunately, with many inspectors. There is, therefore, an understandable reluctance on the part of these men to work with concrete having less than such an excess of workability. Some urging is often required to get them to try a lower slump, less sand, and larger aggregate even where experience has shown that any one or all of these changes to a more efficient mix would be practicable if full use were made of modern vibration equipment. Nevertheless, the committee recommends that such trial be made on each job because with reasonable effort in application, modern vibration will be so effective that surplus workability can be eliminated while improving the quality of the

mix, without adding appreciably to costs of concrete placement and vibration. Where reinforcing steel is congested, smaller aggregate and perhaps another increment of sand will be necessary, but trials will show that good workmanship in placing is more dependent on thoroughness of vibration than on slumps greater than 3 in.

(b) *Mass concrete*—The development, improvement, and use of large sized, rugged, immersion vibrators have been essential factors in permitting the proportioning of mass concrete mixtures to realize fully their advantages as to large aggregate size, stiff consistency, and low mortar content. Present day mass concrete mixtures contain crushed stone or gravel with a maximum size of 6 in., sand contents of 20 percent or less of the combined fine and coarse aggregate, slumps ranging from 1 to 2½ in., and cement contents as low as 1/2 bbl. per cu yd. Such mixtures are low in material costs, generate relatively little heat during hydration, consequently experience little volume change on cooling, shrink little on drying, and possess a minimum tendency to crack, yet possess adequate strength and impermeability. It is hardly necessary to state that such mixes are subject to noticeable change in their placing characteristics with fluctuation in aggregate grading, entrained air content, water content, and cement content. They contain very little built-in "safety factor" from a workability standpoint.

The rate at which this rough-handling mass concrete is produced may run as high as 500 cu yd per hr and be deposited in the forms from 8-cu yd buckets.

(c) *Pavement concrete*—The highly mechanized nature of modern methods for vibrating and finishing concrete pavements permits little compensation for variations in the concrete mix. Therefore, uniform control of the mix is necessary if satisfactory results are to be obtained. Slump should normally be in the range of 1/2 to 1½ in. for concrete to be machine spread and finished.

Plastic mixes of about 1-in. slump are considered desirable at the present time for best operation of mixing, spreading, and finishing equipment. The full potential benefits of vibration will not be obtained until paving mixes with lower slump and sand content become generally accepted, and segregation is avoided or corrected in discharging concrete from the pavers and in dumping concrete on the subgrade. When that time comes, the intensity of vibration will have to be increased over that presently used.

(d) *Floors*—In the case of monolithic finished floors, the topping mix should be proportioned so that the amount of combined aggregate per sack of cement is such that the cement paste slightly overfills voids in the aggregate and enough paste will be brought to the surface to produce a smooth troweled finish. There should be no surplus of paste on the sur-

face. The rough slab is placed as dry as can be worked, with a maximum slump of 2 in.

The topping mix for bonded concrete floor finish should be proportioned to suit the mixed aggregates, so that the cement-and-water paste overfills the voids in the aggregate by about 5 percent.

(e) *Lightweight concrete*—Mix proportions for lightweight concrete (see ACI 613A-59)[3] must be such as to produce a concrete which is workable and which will not segregate during placement and consolidation. Also, to prevent segregation, mixes should be stiffer than those often employed with normal-weight concrete. Properly designed lightweight concrete having a slump of 3 in. is extremely workable and mobile, and it will rarely be necessary or desirable to provide greater slump for normal placement operations; usually less slump is adequate.

For most lightweight aggregates, satisfactory workability may be obtained even with stiff mixes through use of fine natural sand in an amount dependent on the surface character and shape of the aggregate particles. A crushed lightweight aggregate will require a larger percentage of natural sand than will a well rounded aggregate for the same workability.

(f) *Heavyweight Concrete*—Heavyweight concrete mixes are generally harsh and difficult to consolidate. It is essential to select proportions to produce concrete of good workability, usually with higher cement content and higher proportion of sand than for concrete of normal weight. Replacement of 15 to 20 percent of portland cement by finely divided pozzolanic material will improve workability and reduce segregation, resulting in increased density. From the standpoint of improving ease of placement and consolidation, it is desirable to entrain a small percentage of air; however, air entrainment will decrease the density of the concrete somewhat, although some of the air will be removed by vibration.

To prevent segregation, mixes should be stiffer than is the usual practice with concrete of normal weight. The slump of a properly proportioned heavyweight concrete should in no case exceed 3 in., and it should normally be less.

CHAPTER 2—RECOMMENDED PRACTICES

201—General

Each job must be carefully planned and an adequate number of vibrators, of sufficient capacity to more than keep up with the maximum rate of concrete manufacture, should be provided. Sufficient standby equipment should also be provided to keep the placement fully operative when vibrators are undergoing repairs. Vibrators operate under heavy stress and require maintenance the same as other heavy working machinery. Provision should be made for replacement of vibrators that have to be taken out of service for maintenance or repair.

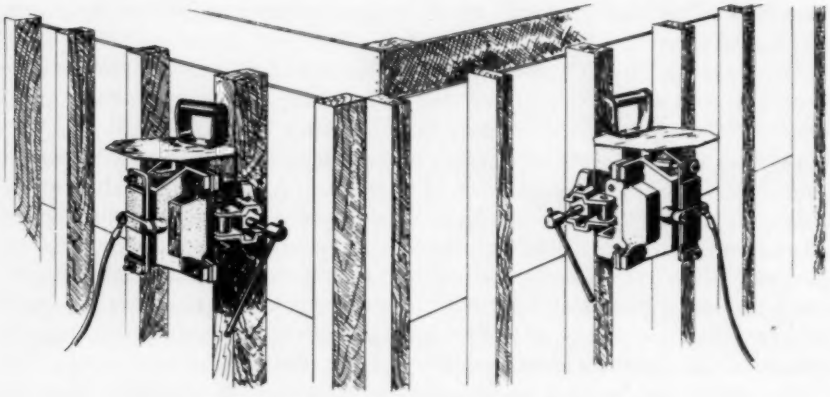

Fig. 2—Electrically powered form vibrators

Internal vibrators should be used in all sections that are sufficiently large for insertion and manipulation of this type. In particularly difficult placements or under certain conditions it may be desirable to supplement the internal vibrators with form vibrators or vibrating screeds. Some prestressed concrete products, due to their small size and congestion of steel, should have both internal and external vibration.

Form vibrators (Fig. 2) should be used where it is impossible to use either the internal or surface type, such as for heavily reinforced thin walls, or pipe and other precast products of small section. The principal direction of vibration should be in a horizontal plane. Vibrators should operate at high frequency and low amplitude. Too great an amplitude is hard on the forms and may cause them to move in such a way as to pump air into the concrete. Vibration of small precast units may be accomplished by mounting the forms or molds on a vibrating table.

Vibrating screeds (Fig. 3) should be used on floors, sidewalks, and other thin slabs. A screed consists of a horizontal member, such as a steel shod heavy timber either straight or shaped to the contour of the surface, on which is mounted one or more vibrating units. It is usually moved over the surface by hand.

Consolidation by such antiquated methods as hand spading or similar means should not be permitted.

(a) *Amount of vibration*—Care must be taken that vibrators are used to consolidate concrete that has been properly placed, and that they are not used to move concrete about in the forms. An exception is discussed under tunnel lining. The higher the speed with which the vibrator operates the less time required for consolidation. However, high frequency alone will not do the job unless amplitude also is adequate. Time required to effect complete consolidation is readily judged by the experienced vibrator man through the "feel" of the vibrator, resumption of frequency of

vibration after the short period of dropping off of frequency when the vibrator is first inserted, appearance of a flattened glistening surface, and cessation of the rise of entrapped air. Vibration should be continued until the coarse aggregate particles have blended into the surface but have not disappeared. Doubt in the mind of the foreman, vibrator operator, or inspector as to the adequacy of vibration should always be resolved by further vibration. Well-proportioned concrete of the correct consistency is not readily susceptible to over-vibration.

A basic requirement of good placement is that if one vibrator is used to melt down the batch at the point of discharge, then one or more additional vibrators must be used to perform the functions of densifying, homogenizing, and surface-perfecting the concrete within the forms.

The purpose of allowing the vibrator to penetrate completely through the layer being placed and into the underlying layer is to weld the two layers together thoroughly. Revibration of the previously placed concrete is beneficial because it rearranges the aggregate particles and eliminates entrapped water from under the aggregate and reinforcing steel, with consequent full contact between mortar and coarse aggregate or between steel and mortar. The resulting concrete is stronger and more watertight.

Every effort should be made to keep the surface of the previously placed layer of concrete alive so that the succeeding layer can be amalgamated with it by the vibration process. However, occasions may arise even on the best planned projects when due to unforeseen circumstances the concrete has hardened in the underlying layer to such an extent that it cannot be pentrated by the vibrator, but is still fresh (just after initial set). In such cases unimpaired bond can be achieved between the top and underlying layers by systematically and thoroughly vibrating the new concrete into contact with the old.

Fear that vibration transmitted directly to reinforcing steel is detrimental appears to be unfounded even when part of the steel is embedded in partially hardened concrete. Although it is not advocated that the reinforcement system be used regularly to transmit vibration to the concrete it is sometimes useful to use the system to vibrate inaccessible areas, and the vibrator operator need not fear that contact between the vibrator and reinforcement will cause damage.

(b) *Effect on entrained air*—Ample vibration, as judged necessary to accomplish thorough consolidation of the most complicated structural concrete, even the extra vibration that will remove air bubble holes, will not damage the parameters of the air void system now known to be essential to best durability, provided the concrete as mixed contains at least the amount of entrained air recommended by ACI Committee 613 in ACI 613-54.[3] During such heavy or prolonged vibration, more than half the initial air content may be lost. Nevertheless, many tests and microscopic measurements have demonstrated that the remaining void system

is unimpaired in its ability to improve durability in freezing and thawing.[39] However, it should be carefully noted that with less than recommended amounts of air entrained initially, the remaining air after vibration may not be enough to provide an effective air void system.

With this assurance, removal of air from air-entrained concrete should not be an inhibiting factor in doing all the vibration that appears to be beneficial. More poor results have occurred as a result of some restraint on the amount of vibration for fear of over-vibration, removal of air, or damage from revibration, than have occurred or are likely to occur from performing an unquestionably ample amount of vibration.

(c) *Air bubble holes*—The degree to which these common imperfections on formed concrete surfaces are objectionable depends on considerations outside the province of this committee. It is appropriate, however, to point out to those who are concerned that:

1. It is nearly impossible to eliminate them from inward-sloping formed surfaces.

2. They can be minimized by using properly proportioned mixes with well graded aggregates, carefully placed and consolidated in shallow lifts, 1 ft or less in depth.

3. They can be substantially eliminated from vertical formed surfaces by additional vibration, which may be as much as twice that normally required only for consolidation and prevention of honeycomb. Vibration should be increased by closer, deeper, and longer penetrations.

4. Form vibration aids materially in reducing them.

(d) *Over-Vibration*—Since in several situations discussed in this report, extra heavy and thorough vibration is recommended, there may be some concern as to the possibility of over-vibration.

There is a possibility of over-vibration, but it is exceedingly unlikely in well proportioned mixes containing normal weight aggregates. The special considerations for lightweight aggregate concrete and for extra heavy concrete are discussed in later sections of this report. If over-vibration occurs it will be immediately evident to an experienced vibrator operator or inspector. The surface of the concrete will have a frothy appearance due to the accumulation of many small air bubbles and the coarse aggregate will have settled beneath the surface. These results are more apt to occur when the concrete is too wet, and the proper correction is to reduce the slump, not the vibration, until evidence of over-vibration disappears during the amount of vibration judged necessary to consolidate the concrete and to eliminate air-bubble blemishes.

The committee suggests that it is well to remember that there are extremely few imperfections in concrete placing workmanship that cannot be corrected by additional vibration. The proper use of vibration will allow the placement and consolidation of concrete in difficult locations and at a comparatively low slump. High slump will not insure good results;

in fact, it will foster separation and unsatisfactory results. The modern concrete vibrator is a remarkable tool with great potential for making practical the use of lower slump concretes. These lower slump concretes provide better quality and greater economy than have been obtained generally in the past. The committee recommends that full use of vibrators be made to gain these benefits without fear of over-vibration.

(e) *Revibration*—Revibration may be defined as the delayed vibration of concrete that has already been placed and consolidated. It may occur when placing successive layers of concrete, and vibrations in the upper layer of fresh concrete are transmitted to the underlying layer which has partially hardened. In some cases it may be done intentionally. Benefits claimed for revibration include improved compressive and bond strength, reduction of honeycomb, release of water trapped under horizontal reinforcing bars, and removal of air and water pockets. Revibration is most effective at the latest time that a running vibrator will sink of its own weight into the concrete and again make it momentarily plastic.

Tests by several investigators have proved that these improvements will result with partially hardened concrete sometimes as long as several hours after casting. Abnormal temperatures and the use of admixtures will alter the length of time after placement when most beneficial revibration can be performed. However, the Portland Cement Association[6] cautions: 'On exposed concrete work where appearance is important, care should be taken to avoid allowing internal vibrators through the fresh concrete into a layer of partially hardened concrete below. If this is permitted a wavy line of demarcation between the layers may appear on the surface. While the quality of the concrete would not be impaired, the wavy line would be objectionable from the standpoint of appearance."

In general, considering the single objection quoted above, and provided the concrete becomes plastic under this vibration, revibration is not harmful and may be beneficial.

(f) *Use of retarders*—It is not within the province of this committee to make recommendations relative to the use of admixtures of any type. The user must decide whether or not an admixture will give the desired results without any injurious side effects. The committee recognizes that there are occasions when better consolidation will be obtained if a set retarding admixture is used to delay the hardening process. For example, in a particularly difficult placement in hot weather where there is great danger of a "cold joint" between successive lifts, it would be desirable to extend the time that a satisfactory joint can be made.

202—Structural concrete

For most structural concrete, vibration is most efficiently performed by means of standard immersion vibrators, either those with flexible shafts (Fig. 1) or those with the motor built into the spud. Performance of

most commercial types now available is generally satisfactory when they are well maintained and suitably powered. Effective vibration is the result of expending into the concrete a sufficient amount of energy to melt it down quickly and consolidate it. For immersion vibrators running in structural concrete, a speed of at least 7000 rpm is recommended. Their successful use is best assured when the newly placed concrete is penetrated (1) vertically, when the concrete is deep enough to embed the vibrator head; otherwise it may be sloped toward the horizontal, as necessary, so the head will operate in a fully embedded position, (2) well into the layer below (if there is one), (3) at frequent regular spacings, amply close together to insure complete consolidation, and (4) long enough (5 to 10 sec ordinarily) in each penetration to fully consolidate at depth.

Form vibrators (Fig. 2) have a useful place in consolidating concrete in precast pipe and structural units, prestressed members, tunnel lining, and as a supplement to internal vibration at locations where steel is usually congested, where concrete cannot be placed directly but must flow into position, or where the internal vibrator cannot be inserted. In any use of form vibration it is important to avoid excessive vibration at any given location. The vibrators should be moved, as necessary, to keep them operating just below the top surface of the concrete, not on empty areas of forms.

In tunnel lining, form vibrators should be used only for lateral movement and vertical settlement and consolidation of arch concrete, not for longitudinal movement. To be most effective they should be attached at one of the upper quarter-points near the end of the concrete delivery pipe, and their operation must be well coordinated for brief vibration during discharge of concrete in the arch, when the arch is nearly full, just before the discharge line is moved back. Vibration, after delivery stops and the pipe is pulled back, will cause settlement and flow of concrete from the arch that cannot be refilled.

An effective way to vibrate concrete around unusually heavy or congested steel is to attach a form vibrator to the steel. It is too hard on equipment to try to vibrate steel by binding an immersion vibrator to it. Although many have suggested possible detriment to bond from vibration carried down through steel to partially set concrete in lower layers of a placement, the committee, on careful examination, has found no grounds for such fears. Apparently amplitude is so dampened that no damage is done; if anything, only beneficial revibration occurs.

Adequacy of vibration is judged mainly by surface appearance. Embedment of large aggregate, general leveling of the batch, apparent blending of the batch perimeter together with concrete previously placed, and general cessation in escape of large bubbles of entrapped air are evidence of, and essential steps to, securing adequate vibration. Sometimes the tendency of vibrator men is merely to flatten the batch. Complete consolida-

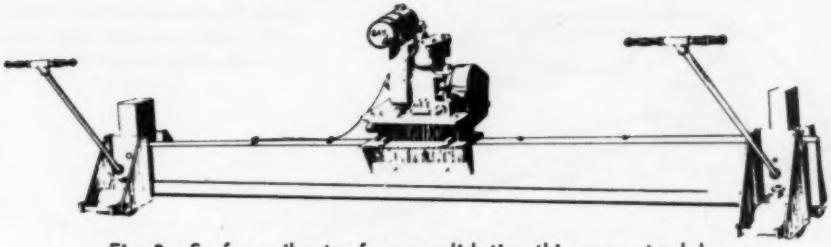

Fig. 3—Surface vibrator for consolidating thin concrete slabs

tion is assured only when these other items of evidence of adequate vibration are sought and attained. Particularly important is vibration at proper depth and spacing.

203—Concrete slabs

Thin slabs, such as sidewalks and floors, are best consolidated by means of a surface vibrator (Fig. 3). The committee recommends that vibrating screeds be used on all slabs less than 8 in. thick, and that such screeds, together with internal vibration, be used on slabs 8 to 12 in. thick. Thicker slabs may be consolidated with immersion vibrators. Screed boards or rails, on which the screed operates, should be set accurately to the proper grade, 1/8 to 1/4 in. above finish grade, depending on the slab thickness.

Vibrating elements should be of the low frequency-high amplitude type, operating at a speed of 3000 to 4500 rpm. If the speed is adjustable, the maximum should be used on the first pass and the minimum on the second.

Pavements, and floors of earth-moist concrete, are covered in other sections of this report.

204—Mass concrete

In the United States, mass concrete is usually placed in 5- or 7½-ft lifts, each lift being made up of a series of 15 to 20 in. courses. Practice in Canada and some other countries frequently permits lifts considerably deeper. The concrete is deposited in piles of up to 8 cu yd, as near as possible to the final position it is to occupy. The concrete is carried in a series of steps across the monolith from the downstream to the upstream end, keeping the exposed area of the concrete to a practical minimum. An excellent account of the manufacture and placement of mass concrete is contained in the U.S. Bureau of Reclamation *Concrete Manual.*[7]

Mass concrete is best consolidated by high-speed immersion vibrators. Machines for this type of work are usually handled by two men although there are ultra-high-speed instruments which do an efficient job of consolidation and require only one man to operate. Frequency of vibrators to consolidate mass concrete should not be less than 6000 rpm when immersed in the concrete for vibrating heads larger than about 4-in. diam-

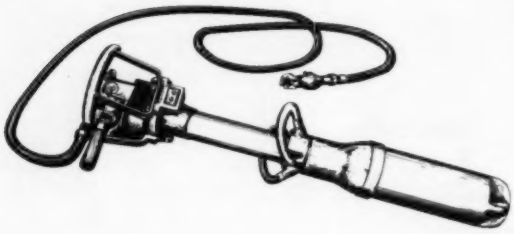

Fig. 4—Heavy-duty two-man pneumatic vibrator for low-slump mass concrete

eter. The minimum frequency of vibrators with heads 4 in. or less in diameter should be 7000 rpm. There are vibrators available that will operate at a speed exceeding 11,000 rpm. Vibrators can be powered either by compressed air (Fig. 4) or electricity (Fig. 5). If powered by air, care must be taken to insure adequate pressure to maintain required speed of vibration. Speed of vibration can be readily checked by means of a vibrating reed tachometer held against the form surface near the vibrator or against the vibrator handle while the vibrator is submerged in concrete.

The amount of concrete that can be handled by one vibrator will vary with the vibrator, the experience of the operators, and the placing characteristics of the concrete. In open areas an efficient crew might handle as much as 40 cu yd per hr per vibrator. The Portland Cement Association pamphlet, *Vibration for Quality Concrete*,[6] suggests 15-40 cu yd per hr for heavy-duty, two-man vibrators. Around embedded items and in complicated formwork the amount handled would be nearer the lower amount stated above.

To handle effectively the large volume of mass concrete entering the form it is necessary to work out a systematic pattern to be followed by the placement crew. The vibrator should be inserted in as nearly a vertical position as possible in the top or near the top of the pile of concrete resulting from discharge of the bucket. Depending on the size of the pile it may be necessary that two or more vibrators evenly spaced around the perimeter be used simultaneously to melt it down. After melting down, the mass should be vibrated to the required depth of layer by systematic vibration of overlapping areas. The spacing for insertion and withdrawal will depend on the vibrator and the concrete being consolidated. The effective radii of vibration should overlap approximately half a radius. Such points of insertion may be 18 to 30 in. apart. It is better to space the points too close than too far apart. The vibrator should be inserted to full depth of the layer being treated and into the underlying layer. The vibrator should be permitted to run in one location until the concrete is thoroughly consolidated, then slowly withdrawn to insure closing the hole resulting from insertion of the vibrator. The length of time to effect thorough consolidation will vary with the workability of the concrete and with the energy imparted by the vibrator. Vibration time may be as short as 5 or as long as 20 sec per point of application.

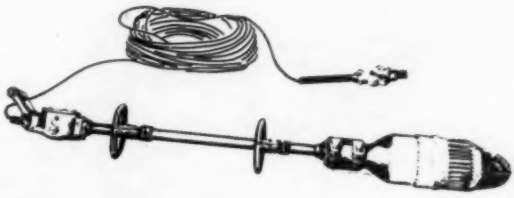

Fig. 5—Heavy-duty two-man electric vibrator for low-slump mass concrete. Motor-in-head type

The use of a small (3-in. diameter high-frequency medium or low amplitude vibrator around the perimeter of the form near but not against the form wall will further reduce incidence of entrapped air voids.

In Europe in recent years, use has been made of gang vibrators to consolidate concrete in dams. Several immersion vibrators are mounted on a frame and inserted into the concrete mass by a heavy piece of power equipment similar to a bulldozer. Gang vibrators might successfully be handled by an overhead crane or similar machine.

205—Concrete pavement

In theory, vibration should be ideal for consolidating pavement concrete, placed at relatively low slump. It is now in general use for thick slabs, such as military airfield pavements, and its use for thinner slabs such as highways is increasing.

Several types of equipment are available for consolidating pavement slabs. While the thickness of the slab is not the only point to be considered in selecting this equipment the committee believes it is the most important single factor involved.

(a) *Vibration of thick pavements*—For pavements 12 in. or more in thickness, internal vibration is necessary to assure adequate consolidation throughout the depth of the slab. The vibrators should be attached to a frame on the rear of the spreader or on a separate carriage which also rides the paving forms, or they may be attached to a frame ahead of the first screed of the finisher. The vibrators should be so arranged that they operate only during their forward movement and so they will all start and stop simultaneously.

Internal spud vibrators similar to those used for consolidating structural concrete, may be mounted on a horizontal frame which is controlled so that the vibrators may be readily raised or lowered (Fig. 6). They should be operated at a fixed position to provide best consolidation, preferably slightly below middepth of the slab but in no case should they extend to within 2 in. of the subgrade. The vibrators should be operated only during forward movement of the carriage. When appreciable segregation occurs by this method, the vibrators should be inserted and withdrawn at intervals no greater than the transverse spacing of the vibrators. Horizontal head L-type vibrators, especially designed for this purpose, are available and should be operated in the same manner.

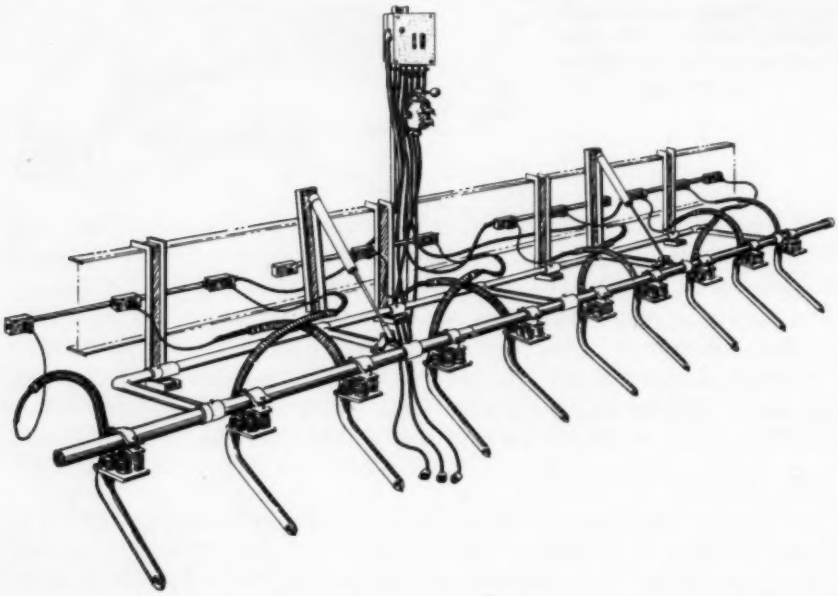

Fig. 6—Spud type internal vibrators gang mounted on a frame permitting easy raising and lowering

The size and spacing of vibrators will be governed mainly by characteristics of the mix and the pavement thickness. In general, vibrator spacings up to 30 in. or double the slab depth, whichever is less, may be used. Spud vibrators have been successfully used for consolidating slabs up to 24 in. thick placed in a single course and it is probable that with special attention to size, frequency, and spacing of vibrators even thicker slabs may be adequately consolidated. Conventional vertically operating spuds may be successfully used for slabs as thin as 12 in.

Satisfactory results can also be secured by using vibratory paving tubes (Fig. 7). Each vibratory unit consists of a motor and two horizontal tubes about 5 ft long which are perpendicular to the pavement centerline. The tubes are suspended below the motor so they can be held near the middepth of the slab without submerging the motor. Sufficient units should be mounted in a line to cover the entire width of the slab, with no more than 4 in. between adjacent tubes, and about 2 in. between the ends of the tubes and forms. Tube vibrators now available are fully adequate for slabs up to 18 in. thick, and even thicker slabs under favorable conditions.

(b) *Vibration of thin pavements*—For pavements 8 in. or less in thickness, the front screed of the finishing machine, when properly adjusted,

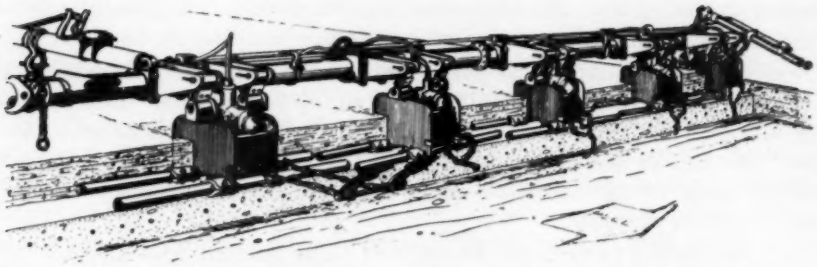

Fig. 7—Vibrating tubes for consolidation of highway and airport concrete. Tubes are shown in a cut-away view in the concrete

provides a compactive effort which may suffice for the interior portion of the slab when a well proportioned concrete mix having a slump of about 1½ in. is used. When additional consolidation is needed, use may be made of surface vibrators of the vibrating screed or pan types (Fig. 8) or gang-mounted immersion spud vibrators of proper design (Fig. 6). Internal spud vibrators, either hand operated or attached to the spreader, should be used along the forms. Hand vibration is also necessary in the vicinity of the joint dowel assemblies and header boards. Special care must be taken to avoid over-vibration which will cause a layer of mortar with high water content along the joint or edge and contribute to raveling and progressive deterioration.

The compactive effort supplied by the finishing machine, however, is not adequate to assure dense concrete under all conditions, especially for slabs 8 to 12 in. thick or for slumps of 1½ in. or less. In this case, it is recommended that use be made of vibrating screed or pan surface vibrators (Fig. 8) or gang-mounted immersion spud vibrators (Fig. 6). Vibrating elements on these screeds should be of the low frequency-high amplitude type. They should be synchronized and operated at a minimum speed of 3500 rpm, and should not be supported on nor touch the forms.

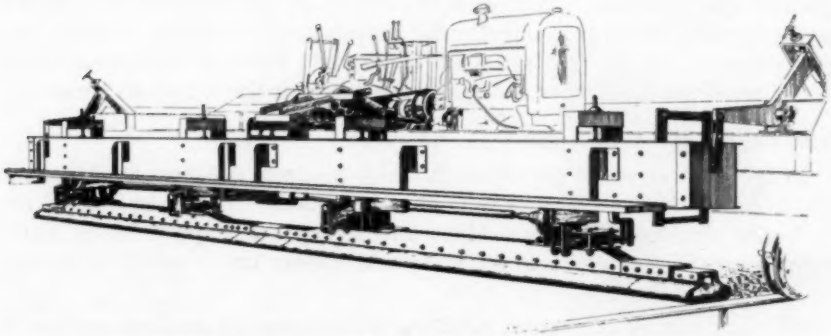

Fig. 8—Vibrating screed for consolidating pavement concrete

Some hand work with spud vibrators will be necessary in the vicinity of joint dowel assemblies and pavement edges.

The vibrator should not be permitted to operate too long in one place, lest segregation result, especially if the slump is too great. Inasmuch as the vibrators are normally incorporated in the concrete spreader or finisher, the rate of forward movement of this machine overcomes the potential danger of too much vibration. When the machine stops, the vibrators should be stopped.

(c) *Reinforced pavement*—Reinforced slabs present special problems in vibration. It is customary to place reinforced pavements in two layers, with the reinforcement placed on top of the first layer. Usually the first layer is thicker than the second, so that the reinforcement will be above the center of the slab.

Where the bottom layer has sufficient thickness to permit their application, the internal vibration techniques previously described should be used. Sometimes it is possible to use tube vibrators or L-type spud vibrators oriented horizontally in the top layer. Where the slab is too thin to permit internal vibration, a surface vibrator should be used on the surface of the upper course.

(d) *Basic principles in successful pavement vibration*—Until more extensive studies are conducted, no specific rule can be stated on the optimum frequency, amplitude, and time of vibration for concrete slabs of various thicknesses and with different concrete materials and mix proportions. The judgment of a competent engineer, who knows how a properly vibrated concrete surface should look and who can predict with reasonable accuracy the radius of influence of the vibrator below the surface, is required. Some degree of flexibility of equipment is essential.

In general, the committee recommends that the operating frequency should not drop below 7000 rpm for spud vibrators, 5000 rpm for tube vibrators, or 3500 rpm for surface vibrators. Vibrators of medium power at relatively close spacing should be used rather than heavy vibrators at greater spacings. The objective is to consolidate the concrete thoroughly and provide just enough mortar for satisfactory finishing without creating a weak, soupy condition at the surface. At least one additional vibrator in good working order should be available on the job at all times.

206—Earth-moist concrete

In the United States use of earth-moist concrete is largely confined to casting such concrete products as pipe and block. It also has limited use in floors where extreme durability and strength are required. In European countries, reports indicate more widespread use of earth-moist concrete for pavements.

The manufacture of precast products is discussed in another section of this report. In regard to pavement and structural use, the committee finds

that such usage enjoys but little vogue, especially in the United States, and can make no recommendation at this time except that research and field tests of equipment and methods for consolidating such dry mixes should be encouraged whenever possible.

(a) *Floors*—In this field some use is made of earth-moist concrete for industrial floors which must resist erosion, chemical action, physical abrasion, impact, and heavy live loading. Obviously, an internal vibrator cannot be used in this construction, and surface consolidation methods must be resorted to. For either a monolithic or bonded finish, a vibrating screed or a power consolidating disc float should be used. The latter machine (Fig. 9) consists of a power-driven rotating float disc. Hammers, mounted on the side of the machine, ride a cam on the float disc. As the disc rotates the hammers are successively raised and dropped on the disc. The resulting force produces a low-order vertical motion and vibration to the disc, effective for consolidation-floating concrete floors.

207—Lightweight concrete

In general, principles and recommended practice for consolidation of concrete of normal weight hold true for concrete made with lightweight aggregates, provided certain precautions are observed.

There is always a tendency for lightweight pieces of aggregate to rise to the surface of fresh concrete, particularly under the action of over-vibration; and a fairly stiff mix, with the minimum amount of vibration necessary to consolidate the concrete in the forms without honeycomb, is the best insurance against undesirable segregation. The rise of lightweight coarse aggregate particles to the surface, caused by over-vibration resulting from too wet a mix, makes finishing difficult if not impossible.

208—Heavyweight concrete

Certain precautions and steps should be taken in placing and consolidating heavyweight concrete to ensure a concrete of uniform density and freedom from segregation.

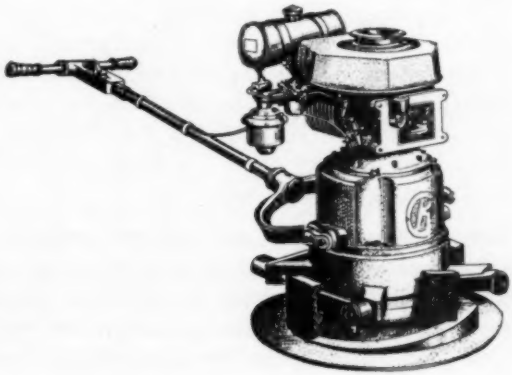

Fig. 9—A rotating disk vibration - consolidation machine, for consolidating floor surfaces

During placement and consolidation there is a tendency for the pieces of heavy aggregate to settle in the fresh concrete, especially if the concrete is too wet, which leads to over-vibration.

When various portions of the aggregate in the mix have about the same specific gravity, segregation during placement and consolidation can be controlled satisfactorily. Steel punchings, however, which have a specific gravity of 7.8, will have a tendency to settle even out of a mix made with usual heavy aggregates of specific gravity 3.5 to 4.7. To prevent segregation of steel punchings in this case is difficult if not impossible, and special methods should be employed for placing and consolidation of concretes containing steel punchings. It is recommended that such concrete be placed by puddling or by the prepacked method.[8]

The puddling method is limited to open forms free of embedded fixtures and consists in placing several inches of mortar in the form and covering it with a layer of coarse heavy aggregate. The coarse aggregate is puddled into place by rodding or internal vibration.

The prepacked method of placing heavyweight concrete eliminates segregation of coarse aggregate and permits close control of density and consolidation. Also the prepacked method avoids the difficulties of placing concrete mixed in the conventional manner around embedded fixtures and in restricted areas. In this method the coarse aggregate is packed in the forms and void spaces are filled with special grout containing heavy sand pumped through grout pipes embedded in the aggregate or through openings in the forms.

In cases where there are many embedded objects, such as heavy reinforcing, pipes and conduits, it is desirable to vibrate these objects during the placement of the aggregate to avoid unfilled pockets. Such vibration will also substantially reduce the void content of the placed aggregate. Vibration of the aggregate mass, however, is unnecessary during pumping of grout into voids of the prepacked aggregate. Where it is desirable to obtain a smooth finish of formed surfaces, forms should be vibrated during grouting.

To summarize, for concretes containing heavy aggregates of uniform density, consolidation can be performed by conventional methods provided the mix is of good workability and the forms are relatively free of embedded fixtures. If the concrete contains mixed aggregates of various densities, or is to be placed in complex forms and around closely spaced embedded fixtures, special methods of placement such as the prepacked method may be necessary.

209—Concrete block and precast products

Because of the considerable number of methods used for the satisfactory production of a great variety of products, the committee is unable to make any recommendations and instead reports what appear to be current good practices. In the manufacture of various precast concrete pro-

ducts, form vibrators are most frequently used, although internal and surface vibrators are also employed. In addition to vibration, various methods of tamping, pressing, jolting, rolling, and spinning also provide ways of obtaining desired compaction and satisfactory placement. These various methods are used to manufacture a wide variety of precast concrete products, such as block, brick, slab, channel, curb, flagstone, roofing tile, floor tile, wall tile, poles, irrigation pipe, pressure pipe, sewer pipe, and joists.

(a) *Concrete block*—Concrete block machines at the present time vary in complexity and productive capacity from the individual block machine requiring considerable manual effort to the super-automatic machines requiring only the correct push-button technique. In some single block machines, vibration alone is used, but in most of the larger block machines, vibration and pressure are employed. Tamping, once important in this field, has largely disappeared.

Concrete block-making machines operate at frequencies varying between 1800 and 7200 rpm. At the lower frequencies, amplitudes of about 1/16 to 1/8 in. are usually used, while at the higher frequencies amplitudes are usually less than 0.05 in. Many block machines operate between 4 and 6 cycles per min. In any given machine, control of the end product is largely effected by changes in concrete mix proportions, amplitude of vibration, and the length of vibration period.

(b) *Precast concrete products*—The greatest variation in placement practices is found in the manufacture of the varied products made by the precast concrete products industry. Plastic concrete may be hand rodded or internally vibrated. Stiff concrete may be placed by hand ramming, machine tamping, form vibrators, hydraulic pressing, machine rolling, or jolting.

Vibration practices apparently vary over a wide range and are usually determined by each manufacturer for the particular equipment he has available and the requirements of his final product. Some manufacturers prefer low amplitude-high frequency vibration, and others prefer high amplitude-low frequency vibration. It does appear, however, that high frequency-low amplitude vibration finds favor in more cases.

In the jolting process of concrete placement, the table or mold is raised by means of cams on one or more revolving shafts and allowed to drop onto the supports. This method might be considered as a vibration of very high amplitude and very low frequency. The mold or table may be allowed to fall a distance of 1/2 in. at a rate of 100 to 200 times per min.

The vibratory unit commonly used consists of a steel channel bolted to the underside of the table, supporting in self-aligning ball bearing pillow blocks a pulley-driven steel shaft and its attached unbalanced weights. Amplitude of this motion may be varied by adjusting the unbalanced weights, and the amount required for a special application depends on

the frequency of vibration and on job requirements. Frequencies commonly used vary between 1500 and 8000 vibrations per min, while the amplitude is usually less than 1/8 in. Period of vibration is commonly between 10 and 20 sec.

(c) *Concrete pipe*—Precast concrete pipe are made by a variety of methods, including automatic tamping, compression by means of a revolving "packerhead," vibration, centrifugation with vibration, and compaction. Irrigation and drain tile and sewer and culvert pipe are usually made by the tamping or packerhead processes unless they are more than 72 in. in diameter. Large size pipe is usually made by some vibration process. High-pressure water pipe is made by vibration or centrifugation. The unit weight of the concrete made with sand and gravel aggregates may be as high as 165 lb per cu ft.

In making tamped pipe, an earth-moist concrete mix is used. A uniform amount of the concrete is fed into the annular space between a stationary core and the outside rotating form and is tamped into place by blows from hardwood tampers fitted with metal shoes which strike at a rate of 500 to 600 times per min. As the pipe wall is built up, the tampers travel up. Besides the compaction provided by the tampers a troweling action is provided as the concrete turns around the stationary core.

An earth-moist concrete mix is also used in the packerhead process. The revolving packerhead starts at the bottom of the vertical form which is the outside form of the finished pipe. As the packerhead revolves at high speed it packs the concrete against the outside form, and since it is also raised as it revolves, the required length of pipe is obtained. The inside diameter of the finished pipe is equal to the outside diameter of the packerhead. The troweling action of the packerhead produces a smooth inside finish.

In making centrifuged pipe the unit water content of the concrete is dependent on materials, equipment, experience, and preference of the individual manufacturer. In this method of pipe manufacture concrete is usually placed in the horizontal mold while it rotates at a slow speed, and the speed is then increased to a higher value so that the centrifugal force compacts the concrete and expels the excess water. The best spinning speed to obtain the densest concrete is apparently found by trial. Values should vary from a peripheral speed of 550 fpm for 6-in. pipe to 3000 fpm for a 60-in. pipe.

Concrete for vibrated pipe may be considered to be structural concrete in many respects. The main difference between usual structural procedures and fabrication of vibrated pipe is the use of external vibrators for the pipe, rather than internal vibrators, because of the difficulty of inserting an internal vibrator into a long, narrow form containing reinforcing steel.

Concrete used in the manufacture of vibrated concrete pipe should have a slump between 2 and 3 in. In this process the forms are vibrated continuously as the concrete is placed. Electric- or air-activated form vibrators are usually used, and they may be rigidly attached to the outer mold slightly below midheight, or moved up as the fill progresses. If only two vibrators are used, they should be attached on diametrically opposite sides of the form and may be connected with an encircling chain to assist in the transmission of the vibration around the perimeter of the form. While in most instances the vibrators are placed on the outside form, they may also be placed on the inside form. Vibration at high frequencies requires heavy forms, tight joints, and positive attachment of the forms to the supporting surface. In large pipe with heavy wall sections, internal vibration should be used.

On forms for concrete pipe, form vibrators should run at least 8000 rmp. It is also important, if surface air bubbles are to have time to rise and escape that concrete be placed in layers not over 24 in. deep and time for 1 to 2 min of vibration be allowed between them. Although this would ordinarily be more vibration than is necessary, when 2-in. slump concrete is used, any tendency toward over-vibration is offset by blending with the next layer. However, to avoid weakness in upper ends as cast, usually spigots, that would result from over-vibration, vibration of the top ring of concrete should be stopped as soon as the newly placed concrete levels and is consolidated.

Another process used in concrete pipe manufacture is one in which the concrete is simultaneously compacted by centrifugal force, high frequency vibration, and a steel roller. The zero-slump concrete used in this process is fed into the molds in layers while the mold revolves at a peripheral speed of about 500 fpm for 30-in. pipe and 100 fpm for 18-in. pipe. with four pneumatic tires which roll on the top sides of the mold. The steel roller running lengthwise through the inside of the pipe is actuated by a hydraulic ram at each end of the mold and provides a maximum compaction pressure of 16,000 lb. Variations of these procedures are also used.

BIBLIOGRAPHY

1. ACI Committee 609, "Recommendations for Placing Concrete by Vibration," ACI JOURNAL, V. 7, No. 4, Mar.-Apr. 1936 (*Proceedings* V. 32), pp. 445-457.

2. Meissner, H. S., "Compacting Concrete by Vibration," ACI JOURNAL, V. 24, No. 10, June 1953 (*Proceedings* V. 49), pp. 885-892.

3. ACI Committee 613, "Recommended Practice for Selecting Proportions for Concrete (ACI 613-54)," ACI JOURNAL, V. 26, No. 1, Sept. 1954 (*Proceedings* V. 51), pp. 49-64. Also see "Recommended Practice for Selecting Proportions for Structural Lightweight Concrete (ACI 613A-59)," American Concrete Institute, 1959, pp. 1-10.

4. ACI Committee 318, "Building Code Requirements for Reinforced Concrete (ACI 318-56)," ACI JOURNAL, V. 27, No. 9, May 1956 (*Proceedings* V. 52), pp. 913-986.

5. Tucker, J., Jr.; Pigman, G. L.; Pissappia, E. A.; and Rogers, J. S., "Study of Vibrated Concrete," *Journal of Research*, The National Bureau of Standards, Nov. 1937, p. 575.

6. *Vibration for Quality Concrete*, Portland Cement Association, Mar. 1938.

7. *Concrete Manual*, U. S. Bureau of Reclamation, 6th Edition, 1956, pp. 268-272.

8. Davis, Harold S., "How to Choose and Place Mixes for High-Density Concrete Reactor Shields," *Nucleonics*, June 1955, pp. 60-65.

9. *Standard Guide Specifications for Concrete, CE 1401.01*, U. S. Army, Corps of Engineers, Oct. 1953, p. 19.

10. Timms, A. G., "Application of Vibration to Concrete Pavement Construction," ACI JOURNAL, V. 24, No. 10, June 1953 (*Proceedings* V. 49), pp. 933-942.

11. Arms, L. M., "Placing and Finishing Concrete," *Construction Methods and Equipment*, Apr. 1956.

12. "Concrete Pavement Vibrator Studies," *SWDGL Report* No. 2064 (unpublished), S. W. Division Laboratory, U. S. Army, Corps of Engineers.

13. "Symposium on Vibration of Concrete," ACI JOURNAL, V. 24, No. 10, June 1953 (*Proceedings* V. 49), pp. 885-956.

14. "The Vibration of Concrete," *Joint Committee Report*, Institution of Civil Engineers and Institution of Structural Engineers, London, 1956.

15. *Guide Specifications for Concrete Pavement, CE-806*, U. S. Army, Corps of Engineers, Apr. 1956, pp. 37-39.

16. "Standard Practice for Concrete Pavements," *Engineering Manual for Military Construction*, U. S. Army, Corps of Engineers, Part XII, Chapter 7, Apr. 1956, pp. 50-51 (draft).

17. L'Hermite, L., and Tournon, G. ,"The Vibration of Fresh Concrete," *Annales*, Institut Technique du Batiment et des Travaux Publics (Paris), Feb. 1948.

18. "Effect of Vibration Time upon Loss of Entrained Air from Concrete Mixes," *Materials Laboratory Report* No. CE-461, U. S. Bureau of Reclamation, Nov. 1949.

19. Plowman, J. M., "Recent Research on the Vibration of Concrete," *Journal*, Reinforced Concrete Association (London), Sept. 1956.

20. *High Quality Concrete by Vibration Methods*, Swedish Cement Association, Stockholm, Mar. 1944.

21. Clemmer, H. F., and Downey, Paul W., "Vibration in Placement of Concrete," *Proceedings*, Highway Research Board, V. 21, 1941, p. 272.

22. Hornibrook, F. B., "Measurements of Amplitudes in Paving Concrete Being Compacted by Vibration," *Proceedings*, Highway Research Board, V. 21, 1941, p. 279.

23. Foster, Bruce E., "Use of Admixtures as Integral Waterproofing and Dampproofing Materials," ACI JOURNAL, V. 22, No. 1, Sept. 1950, (*Proceedings* V. 47), pp. 46-52.

24. "Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete," Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, June 1940, pp. 32-39 (out of print).

25. "Crackless Concrete for Hiwassee Dam," *Engineering News-Record*, Sept. 14, 1939, pp. 69-72.

26. Amirikian, Arsham, "Extent and Acceptability of Cracking in Precast Concrete Framing Members," ACI JOURNAL, V. 21, No. 9, May 1950 (*Proceedings* V. 46), pp. 689-692.

27. *Concrete Pavement Manual*, Portland Cement Association, June 1946, p. 69.

28. Friberg, Bengt F., "Some Observations on the Use of Reinforcing Steel in Concrete Pavements," ACI JOURNAL, V. 22, No. 1, Sept. 1950 (*Proceedings*, V. 47), pp. 1-16.

29. Elgar, W. H., "Soil Movements as Affecting Paved Surfaces," *Surveyor* (London), 1944, pp. 427-428.

30. Paxson, G. S., "Maintenance and Repair of Concrete Bridges on the Oregon Highway System," ACI JOURNAL, V. 17, No. 2, Nov. 1945 (*Proceedings* V. 42), pp. 105-114.

31. Jackson, F. H., and Tyler I. L., "Long-Time Study of Cement Performance in Concrete. Chapter 7—New York Test Road," ACI JOURNAL, V. 22, No. 10, June 1951 (*Proceedings* V. 47), pp. 773-796.

32. Davis, Raymond E., and Troxell, G. E., "Properties of Concrete and Their Influence on Prestress Design," ACI JOURNAL, V. 25, No. 5, Jan. 1954 (*Proceedings* V. 50), pp. 381-391.

33. McIntosh, J. D., "Basic Principles of Concrete Mix Design," *Symposium on Mix Design and Quality Control of Concrete*, Cement and Concrete Association, London, May 1954.

34. Blanks, R. F., and Gilliland, J. L., "False Set in Portland Cement," ACI JOURNAL, V. 22, No. 7, Mar. 1951 (*Proceedings* V. 47), pp. 517-532.

35. Murdock, L. J., "Methods of Achieving Control of Quality," *Symposium on Mix Design and Quality Control of Concrete*, Cement and Concrete Association, London, May 1954.

36. Barrett, Cornelius R., "Revibration Puts More Life in Concrete," *Engineering News-Record*, Mar. 10, 1955, p. 42.

37. Tuthill, Lewis H., and Davis, Harmer E., "Overvibration and Revibration of Concrete," ACI JOURNAL, V. 10, No. 1, Sept. 1938 (*Proceedings* V. 55), pp. 41-47.

38. Davies, R. D., "Some Experiments on the Compaction of Concrete by Vibration," *Magazine of Concrete Research* (London), No. 8, Dec. 1951 pp. 71-78.

39. Backstrom, James E.; Burrows, Richard W.; Mielenz, Richard C.; Flack, Harry L.; Wolkodoff, Vladimir E., "Origin, Evolution, and Effects of the Air Void System in Concrete," ACI JOURNAL, V. 30, No. 1-4, July-Oct. 1958 (*Proceedings* V. 55), pp. 95-121, 261-272, 359-375, and 507-517.

40. Georgii, Hans; Ramhem, Lars; Wretlind, Nils, "Revibrering av Betong," *Examensarbete vid Institutionen för Byggnadsteknik* (Stockholm), 1956.

41. Higginson, Elmo C., "Some Effects of Vibration and Handling on Concrete Containing Entrained Air," ACI JOURNAL, V. 24, No. 1, Sept. 1952 (*Proceedings* V. 49), pp. 1-12.

42. "A Primer on Vibration," *Concrete Construction*, V. 4, No. 3, Mar. 1959, pp. 1-4; No. 4, Apr. 1959, pp. 1-3.

43. ACI Committee 614, "Recommended Practice for Measuring, Mixing, and Placing Concrete (ACI 614-59)," American Concrete Institute, 1959, pp. 1-31.

This report was submitted to letter ballot of the committee which consists of 12 members; 12 members returned their ballots, of whom 11 have voted affirmatively and 1 negatively.

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Title No. 56-50

Internal Forces in Uniformly Loaded Helicoidal Girders

By A. C. SCORDELIS

General equations for determination of redundants at midspan of a uniformly loaded helicoidal girder fixed at its ends are given. Tabulated results, for these redundants, obtained with the aid of a digital computer, are presented for 510 different cases, the variables being horizontal angle, angle of slope, and cross-sectional dimensions. The effect of these variables on the redundants and the maximum internal moments and torques is discussed.

THE DESIGN OF REINFORCED AND PRESTRESSED concrete helicoidal stairs has recently received the attention of a number of writers. Bergman[1] suggests an approximate method of analysis, which reduces the analysis to that of a horizontal bow girder. More accurate procedures based on an analysis of the longitudinal elastic axis of the girder as a three dimensional indeterminate structure have been presented by Fuchsteinner,[2] Gedizli,[3] Cohen,[4] and Holmes.[5] Holmes' excellent paper is perhaps the most comprehensive treatment of the subject. Young and Scordelis[6] investigated the accuracy of the theories being used by conducting an experimental study on four plexiglas models.

While an analysis of the longitudinal elastic axis of the girder as a three dimensional structure is not difficult in concept, the formulas involved are quite lengthy and complex and thus there are considerable possibilities for computational errors. Problems of this type are suitable for solution by a digital computer.

It is the purpose of this paper to present the following:

a. General equations for the determination of the redundants at midspan of a uniformly loaded helicoidal girder fixed at the ends. (Formulas which accomplish the same purpose, but are in a different form have also been developed by Holmes.[5])

b. Tabulated results for the midspan redundants of 510 different girders having rectangular cross sections, the variables being horizontal angle, angle of slope, and width-depth ratio of cross section. These results were obtained with the aid of an IBM 701 digital computer.

c. Values of maximum moments and torques for a number of the above cases together with a discussion of the effect of the variables on these maximum values.

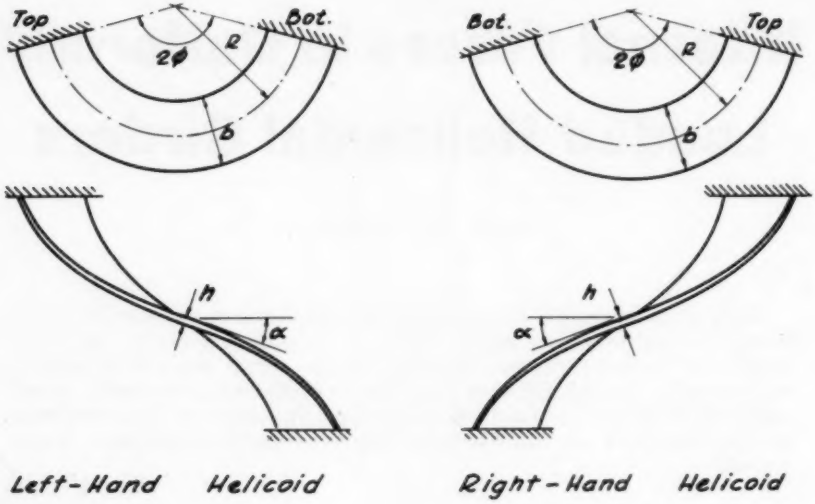

Fig. 1—Geometry of helicoidal girders

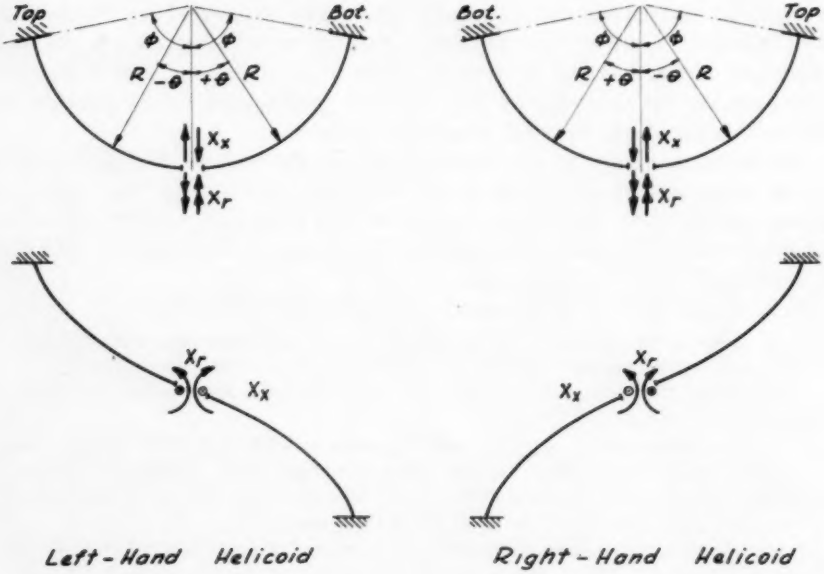

Fig. 2—Positive direction of redundants

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The geometry of a helicoidal girder may be defined, as shown in Fig. 1, in terms of its centerline radius, R; horizontal angle, 2ϕ; angle of slope, α; width, b; and depth, h. The helicoid may be either left-hand or right-hand as shown in Fig. 1.

ANALYTICAL SOLUTION

The helicoidal girder will be analyzed for a uniform vertical load of 1 lb per lineal ft of *horizontal projection* of the girder longitudinal axis. The girder, which is fixed at the ends, is statically indeterminate to the sixth degree. By selecting the redundants at midspan, and using principles of symmetry, all but two of the redundants become equal to zero. This greatly simplifies the problem. The two redundants at the midspan cut are: X_z, a horizontal force in the direction of the x-axis; and X_r, a moment acting about the x-axis. These are shown with their positive directions in Fig. 2. A moment vector is shown with a double arrowhead. The vector indicates the axis about which the moment acts and the right hand rule should be used to determine the direction of the moment.

Using the principle of superposition the displacements in the direction of the redundants may be written as follows:

$$\delta_{zw} + X_z\delta_{zz} + X_r\delta_{zr} = 0 \quad \text{(1)}$$

$$\delta_{rw} + X_z\delta_{rz} + X_r\delta_{rr} = 0 \quad \text{(2)}$$

In the above equations the δ terms indicate relative displacements of the two ends of the girder at the midspan cut:

- δ_{zw} = relative linear displacement in the direction of the x-axis due to a uniform load of 1 lb per lineal ft of horizontal projection with the redundants equal to zero
- δ_{rw} = relative angular displacement about the x-axis due to a uniform load load of 1 lb per ft of horizontal projection with the redundants equal to zero
- δ_{zz} = relative linear displacement in the direction of the x-axis due to $X_z = 1$
- δ_{rz} = relative angular displacement about the x-axis due to $X_z = 1$
- δ_{zr} = relative linear displacement in the direction of the x-axis due to $X_r = 1$
- δ_{rr} = relative angular displacement about the x-axis due to $X_r = 1$

By Maxwell's law of reciprocal displacements $\delta_{rz} = \delta_{zr}$. To solve Eq. (1) and (2) for the redundants, five displacements must be determined

$$\delta_{zw},\ \delta_{rw},\ \delta_{zz},\ \delta_{rr},\ \text{and}\ \delta_{rz} = \delta_{zr}.$$

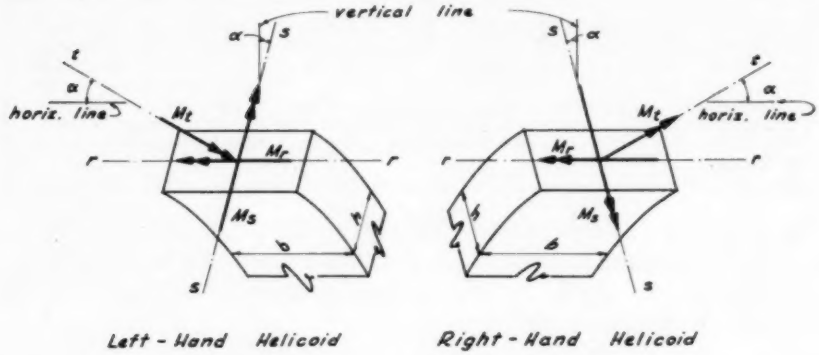

Fig. 3—Positive direction of bending and torsional moments

Any method may be used to determine the displacements, one of the most direct being the method of virtual work. For example:

$$\delta_{sw} = \int_{-\phi}^{+\phi} \frac{m_{rs} m_{rw} R d\phi}{EI_r} + \int_{-\phi}^{+\phi} \frac{m_{ss} m_{sw} R d\phi}{EI_s} + \int_{+\phi}^{-\phi} \frac{m_{ts} m_{tw} R d\phi}{GJ_t}$$

m_{rw}, m_{sw}, and m_{tw} represent bending and torsional moments in the girder due to the uniform load of 1 lb per lineal ft of horizontal projection with the redundants equal to zero. Referring to Fig. 2 and Fig. 3, at any location θ from midspan these may be expressed by statics as follows:

$$m_{rw} = -R^2 (1 - \cos \theta) \quad (3)$$

$$m_{sw} = -R^2 (\theta - \sin \theta) \sin \alpha \quad (4)$$

$$m_{tw} = -R^2 (\theta - \sin \theta) \cos \alpha \quad (5)$$

m_{rx}, m_{sx}, and m_{tx} represent bending and torsional moments in the girder due to $X_x = 1$:

$$m_{rx} = -R (\theta \sin \theta) \tan \alpha \quad (6)$$

$$m_{sx} = R (\sin \theta) \cos \alpha + R (\theta \cos \theta) \sin \alpha \tan \alpha \quad (7)$$

$$m_{tx} = -R (\sin \theta) \sin \alpha + R (\theta \cos \theta) \sin \alpha \quad (8)$$

m_{rr}, m_{sr}, and m_{tr} represent bending and torsional moments in the girder due to $X_r = 1$:

$$m_{rr} = \cos \theta \quad (9)$$

$$m_{sr} = \sin \theta \sin \alpha \quad (10)$$

$$m_{tr} = \sin \theta \cos \alpha \quad (11)$$

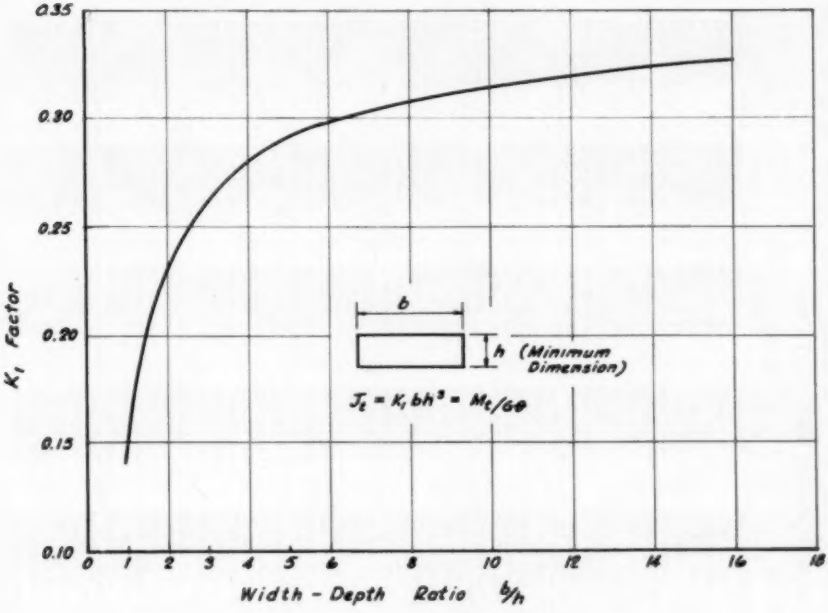

Fig. 4—Torsion constant for rectangular sections

EI_r and EI_s represent the bending stiffnesses about the r and s-axes, respectively, and GJ_t represents the torsional stiffness about the t-axis. For rectangular cross sections EI_r and EI_s can be easily calculated. G can be taken equal to 3/7 E for concrete and J_t can be calculated by means of the expression $J_t = k_1 bh^3$ in which k_1 is a constant depending on the width-depth ratio of the cross section. Values of k_1 are given by Timoshenko and Goodier[7] (p. 277), and are plotted in Fig. 4 for convenience.

General formulas for each of the five displacements needed in the solution of Eq. (1) and (2) have been derived and are given in the appendix to this paper. They are expressed in terms of the horizontal angle, ϕ; angle of slope, α; centerline radius, R; and the bending and torsional stiffnesses.

Once X_s and X_r have been determined by Eq. (1) and (2), the final bending and torsional moments at any section of the girder may be found by superposition utilizing Eq. (3) thru (11)

$$M_r = m_{rw} + X_s m_{rs} + X_r m_{rr} \quad \text{(12)}$$

$$M_s = m_{sw} + X_s m_{ss} + X_r m_{sr} \quad \text{(13)}$$

$$M_t = m_{tw} + X_s m_{ts} + X_r m_{tr} \quad \text{(14)}$$

TABLE 1—REDUNDANTS AT MIDSPAN OF A HELICOIDAL GIRDER, FIXED AT THE ENDS, AND UNDER A UNIFORM LOAD OF 1 LB PER LINEAL FT OF HORIZONTAL PROJECTION.

ϕ, deg	b/h	$\alpha = 0$ deg		$\alpha = 10$ deg		$\alpha = 20$ deg		$\alpha = 30$ deg		$\alpha = 40$ deg	
		X_r/R^2	X_s/R	X_r/R^2	X_s/R	X_r/R^2	X_s/R	X_r/R^2	X_s/R	X_r/R^2	X_s/R
30	0.5	0.041076	—	0.041208	—0.004116	0.041594	—0.007869	0.042207	—0.010887	0.042999	—0.012797
30	1	0.043322	—	0.043334	—0.009661	0.043369	—0.018073	0.043428	—0.024179	0.043505	—0.027262
30	2	0.044048	—	0.043728	—0.030222	0.042845	—0.055063	0.041599	—0.070868	0.040227	—0.076396
30	4	0.044275	—	0.042727	—0.109131	0.038878	—0.184471	0.034291	—0.215325	0.030112	—0.210354
30	8	0.044361	—	0.038532	—0.385391	0.028060	—0.522146	0.019961	—0.492779	0.014878	—0.409781
30	16	0.044419	—	0.027542	—1.097503	0.013173	—0.984363	0.007341	—0.736407	0.004771	—0.541834
45	0.5	0.084399	—	0.084856	—0.008396	0.086215	—0.016272	0.088434	—0.023007	0.091408	—0.027818
45	1	0.091580	—	0.091604	—0.022632	0.091685	—0.042052	0.091846	—0.055700	0.092101	—0.062078
45	2	0.094384	—	0.092711	—0.073760	0.088366	—0.129104	0.082827	—0.157377	0.077432	—0.160232
45	4	0.095316	—	0.087491	—0.259936	0.071214	—0.388273	0.056193	—0.397939	0.045439	—0.349765
45	8	0.095679	—	0.069560	—0.813138	0.039261	—0.851112	0.023890	—0.682997	0.016416	—0.519113
45	16	0.095926	—	0.037744	—1.780030	0.013349	—1.223991	0.006420	—0.836442	0.003742	—0.592805
60	0.5	0.137938	—	0.138914	—0.014025	0.141845	—0.027504	0.146720	—0.039629	0.153431	—0.049111
60	1	0.150083	—	0.150027	—0.042739	0.149932	—0.078546	0.149975	—0.102414	0.150319	—0.112140
60	2	0.155808	—	0.150415	—0.144949	0.137538	—0.239496	0.123213	—0.272267	0.111236	—0.259827
60	4	0.157861	—	0.133892	—0.489717	0.094559	—0.627539	0.067153	—0.568310	0.051318	—0.460807
60	8	0.158683	—	0.090051	—1.314476	0.039912	—1.102437	0.021447	—0.803525	0.013704	—0.584536
60	16	0.159251	—	0.037173	—2.296157	0.009434	—1.365275	0.002686	—0.898438	0.000498	—0.627743
75	0.5	0.200967	—	0.202616	—0.021899	0.207580	—0.043295	0.215863	—0.063168	0.227325	—0.079504
75	1	0.212661	—	0.212200	—0.072515	0.211131	—0.131078	0.210178	—0.167036	0.210012	—0.178462
75	2	0.219151	—	0.206056	—0.252559	0.178068	—0.387301	0.151645	—0.407153	0.132971	—0.364845
75	4	0.221661	—	0.167748	—0.800721	0.100738	—0.871921	0.065065	—0.714348	0.047728	—0.548549
75	8	0.222696	—	0.092048	—1.822119	0.031194	—1.294589	0.013305	—0.893144	0.006464	—0.635362
75	16	0.223421	—	0.027304	—2.687546	0.001107	—1.475694	—0.004409	—0.953867	—0.006377	—0.662180
90	0.5	0.273239	—	0.275669	—0.033857	0.282922	—0.067141	0.294823	—0.098306	0.310850	—0.124002
90	1	0.273239	—	0.271648	—0.115961	0.267888	—0.204678	0.264138	—0.252760	0.262230	—0.261594
90	2	0.273239	—	0.247271	—0.405324	0.198838	—0.568826	0.160689	—0.552592	0.138015	—0.468726
90	4	0.273239	—	0.176914	—1.180833	0.087961	—1.103350	0.050548	—0.839859	0.034723	—0.622896
90	8	0.273239	—	0.074678	—2.296652	0.013844	—1.454486	—0.001500	—0.972278	—0.006986	—0.683421
90	16	0.273239	—	0.009015	—3.011908	—0.013079	—1.581411	—0.017545	—1.012780	—0.019090	—0.700826
105	0.5	0.353387	—	0.356578	—0.053086	0.365887	—0.104873	0.380430	—0.152259	0.398526	—0.189137
105	1	0.325434	—	0.321414	—0.178985	0.312115	—0.305653	0.302959	—0.362323	0.297753	—0.360764
105	2	0.306326	—	0.262535	—0.610009	0.192748	—0.776367	0.147167	—0.701012	0.124411	—0.568821
105	4	0.298058	—	0.155447	—1.607294	0.057541	—1.317495	0.023627	—0.952944	0.010905	—0.691558
105	8	0.294489	—	0.040179	—2.730375	—0.013225	—1.601731	—0.025405	—1.051092	—0.029537	—0.733936
105	16	0.291931	—	—0.018737	—3.310577	—0.036114	—1.693755	—0.039570	—1.079268	—0.040801	—0.745618
120	0.5	0.437448	—	0.441041	—0.084891	0.450991	—0.165465	0.464864	—0.234410	0.479052	—0.280716
120	1	0.361869	—	0.353410	—0.269651	0.334761	—0.440502	0.317489	—0.496372	0.307827	—0.472902
120	2	0.308044	—	0.243647	—0.869644	0.157243	—1.000646	0.110263	—0.847884	0.090614	—0.664857
120	4	0.284184	—	0.103739	—2.056594	0.010218	—1.518004	—0.017603	—1.000629	—0.026967	—0.759291
120	8	0.273775	—	—0.010207	—3.133510	—0.053051	—1.748097	—0.062315	—1.134474	—0.065452	—0.789181
120	16	0.266275	—	—0.058980	—3.606203	—0.071994	—1.817648	—0.074747	—1.154920	—0.075943	—0.797233
135	0.5	0.517091	—	0.520008	—0.137651	0.527018	—0.261144	0.533698	—0.353748	0.535348	—0.399362
135	1	0.373674	—	0.358114	—0.397681	0.326190	—0.613379	0.299286	—0.651372	0.285198	—0.592017
135	2	0.271217	—	0.186920	—1.182048	0.092401	—1.232561	0.049027	—0.990564	0.033795	—0.756868
135	4	0.225714	—	0.024863	—2.511029	—0.055723	—1.709731	—0.077298	—1.166844	—0.084143	—0.828027
135	8	0.205847	—	—0.078084	—3.518682	—0.110531	—1.898760	—0.117743	—1.223721	—0.120676	—0.849309
135	16	0.191526	—	—0.116594	—3.915677	—0.126209	—1.953642	—0.128834	—1.239189	—0.130611	—0.854980

150	0.5	0.577551	—	0.577662	—0.223142	0.575713	—0.404677	0.567208	—0.512710	0.550109	—0.536334
150	1	0.350603	—	0.325133	—0.572046	0.277669	—0.821935	0.242145	—0.817975	0.225087	—0.709425
150	2	0.192796	—	0.092440	—1.537720	—0.001655	—1.462469	—0.039153	—1.125771	—0.050801	—0.843191
150	4	0.123831	—	—0.079416	—2.956437	—0.144700	—1.893538	—0.161676	—1.271165	—0.167847	—0.896403
150	8	0.093933	—	—0.167960	—3.889826	—0.192222	—2.052113	—0.198809	—1.316221	—0.202983	—0.911754
150	16	0.072461	—	—0.198088	—4.230065	—0.205686	—2.097066	—0.209174	—1.328321	—0.212772	—0.915770
165	0.5	0.596271	—	0.590908	—0.354034	0.574389	—0.601356	0.547506	—0.700210	0.514359	—0.675214
165	1	0.282126	—	0.245048	—0.795183	0.183625	—1.052814	0.143319	—0.981188	0.125530	—0.814990
165	2	0.073636	—	—0.037862	—1.915886	—0.126220	—1.677293	—0.158537	—1.246782	—0.169228	—0.918692
165	4	—0.015053	—	—0.210360	—3.373153	—0.262934	—2.062226	—0.278153	—1.367159	—0.286477	—0.958495
165	8	—0.053057	—	—0.286239	—4.233941	—0.305606	—2.197786	—0.313571	—1.403718	—0.321310	—0.969610
165	16	—0.060188	—	—0.310880	—4.530723	—0.318170	—2.235257	—0.324071	—1.413139	—0.331625	—0.972209
180	0.5	0.544626	—	0.533344	—0.535416	0.504417	—0.837848	0.467360	—0.892159	0.429740	—0.800215
180	1	0.159663	—	0.112224	—1.503926	0.043257	—1.280160	0.003424	—1.123000	0.013179	—0.898887
180	2	0.082543	—	—0.201781	—2.279407	—0.283465	—1.857321	—0.313307	—1.341406	—0.326554	—0.973670
180	4	0.182557	—	—0.371143	—3.725656	—0.416298	—2.197268	—0.433084	—1.440562	—0.446932	—1.002313
180	8	0.224880	—	—0.439044	—4.514182	—0.457078	—2.313701	—0.468747	—1.470013	—0.482994	—1.009669
180	16	0.254901	—	—0.461348	—4.773306	—0.470157	—2.343959	—0.480404	—1.476380	—0.494722	—1.010414
210	0.5	0.138656	—	0.143123	—0.959359	0.146748	—1.281012	0.141380	—1.191133	0.129030	—0.977473
210	1	—0.253758	—	—0.303236	—1.517784	—0.360020	—1.589483	—0.387623	—1.275368	—0.399625	—0.968848
210	2	—0.482586	—	—0.617047	—2.732584	—0.691998	—1.998190	—0.723837	—1.376626	—0.747498	—0.965437
210	4	—0.573345	—	—0.780919	—3.992191	—0.824870	—2.231863	—0.849703	—1.423911	—0.877863	—0.960705
210	8	—0.611124	—	—0.845829	—4.602923	—0.867509	—2.303911	—0.888899	—1.433136	—0.918160	—0.954800
210	16	—0.637701	—	—0.869484	—4.773669	—0.883670	—2.311273	—0.904020	—1.427230	—0.933425	—0.947163
240	0.5	—0.619776	—	—0.557047	—1.158406	—0.461190	—1.458352	—0.404281	—1.303372	—0.380875	—1.047730
240	1	—0.830873	—	—0.859716	—1.609721	—0.888845	—1.569728	—0.901670	—1.209217	—0.907155	—0.894175
240	2	—0.955151	—	—1.098797	—2.537456	—1.166310	—1.739706	—1.191649	—1.150480	—1.208837	—0.771906
240	4	—1.004686	—	—1.238443	—3.405029	—1.276583	—1.824418	—1.292996	—1.116984	—1.308792	—0.711082
240	8	—1.025347	—	—1.294769	—3.771439	—1.310824	—1.833255	—1.322583	—1.093912	—1.336944	—0.683736
240	16	—1.039896	—	—1.313751	—3.827667	—1.322291	—1.807347	—1.332530	—1.069967	—1.346206	—0.664680
270	0.5	—1.424413	—	—1.352116	—1.007499	—1.238559	—1.288706	—1.168357	—1.166242	—1.137506	—0.945914
270	1	—1.424413	—	—1.442070	—1.287158	—1.456337	—1.221024	—1.457658	—0.923333	—1.452703	—0.672212
270	2	—1.424413	—	—1.538460	—1.780086	—1.575878	—1.158018	—1.574116	—0.735006	—1.559848	—0.469461
270	4	—1.424413	—	—1.600753	—2.161736	—1.610341	—1.107220	—1.595027	—0.643458	—1.569661	—0.379324
270	8	—1.424413	—	—1.621437	—2.278884	—1.614904	—1.068130	—1.594626	—0.602367	—1.565586	—0.344296
270	16	—1.424413	—	—1.621697	—2.248854	—1.610309	—1.026752	—1.589006	—0.573263	—1.559532	—0.323931
300	0.5	—2.055567	—	—2.027540	—0.659080	—1.986676	—0.840066	—1.967165	—0.758852	—1.965688	—0.615299
300	1	—1.898761	—	—1.914479	—0.736045	—1.922300	—0.670079	—1.914892	—0.495208	—1.899586	—0.354710
300	2	—1.794951	—	—1.842794	—0.815401	—1.839727	—0.496553	—1.809353	—0.298012	—1.764670	—0.176558
300	4	—1.750854	—	—1.810232	—0.836811	—1.789534	—0.401246	—1.746082	—0.211634	—1.686446	—0.104336
300	8	—1.731969	—	—1.791593	—0.812350	—1.764561	—0.356835	—1.717748	—0.177878	—1.654431	—0.078603
300	16	—1.718492	—	—1.773848	—0.762197	—1.745629	—0.325098	—1.698909	—0.157627	—1.636090	—0.065210
330	0.5	—2.455802	—	—2.457557	—0.166402	—2.463137	—0.201832	—2.472028	—0.176733	—2.482815	—0.141101
330	1	—2.169622	—	—2.167748	—0.033423	—2.159161	—0.025408	—2.144199	—0.014258	—2.124698	—0.006237
330	2	—1.980714	—	—1.960950	0.202014	—1.932233	—0.139400	—1.890001	0.105990	—1.834186	0.086008
330	4	—1.900600	—	—1.866721	0.382537	—1.832707	0.217257	—1.779437	0.155444	—1.707137	0.121853
330	8	—1.866316	—	—1.827336	0.462721	—1.793032	0.246069	—1.737218	0.172611	—1.660918	0.133627
330	16	—1.841856	—	—1.801983	0.501089	—1.768220	0.260715	—1.712700	0.180963	—1.636850	0.138823
360	0.5	—2.544626	—	—2.536417	0.416540	—2.527916	0.423058	—2.524968	0.336527	—2.524900	0.254438
360	1	—2.159663	—	—2.128036	0.669718	—2.102585	0.523786	—2.084595	0.371531	—2.066677	0.266395
360	2	—1.917456	—	—1.857526	1.034323	—1.822874	0.610082	—1.782178	0.396388	—1.729006	0.271499
360	4	—1.817442	—	—1.744724	1.261416	—1.710863	0.644787	—1.659966	0.404313	—1.589354	0.271430
360	8	—1.775119	—	—1.701680	1.338566	—1.668923	0.652861	—1.615325	0.404960	—1.540013	0.270102
360	16	—1.745098	—	—1.676386	1.354151	—1.644241	0.651848	—1.590523	0.402973	—1.515037	0.268166

RESULTS FOR REDUNDANTS AT MIDSPAN

An inspection of formulas given in the appendix for the displacements needed in determining the redundants will indicate that they are lengthy and complex. In an actual numerical case extreme care must be taken in the computational work to avoid mistakes. To eliminate this difficulty the general solution for the redundants was programmed for an IBM 701 digital computer, and numerical values for the redundants were obtained for a wide range of variables.

The problem was ideally suited for a digital computer. The amount of input data was small consisting, for each case, of the horizontal angle

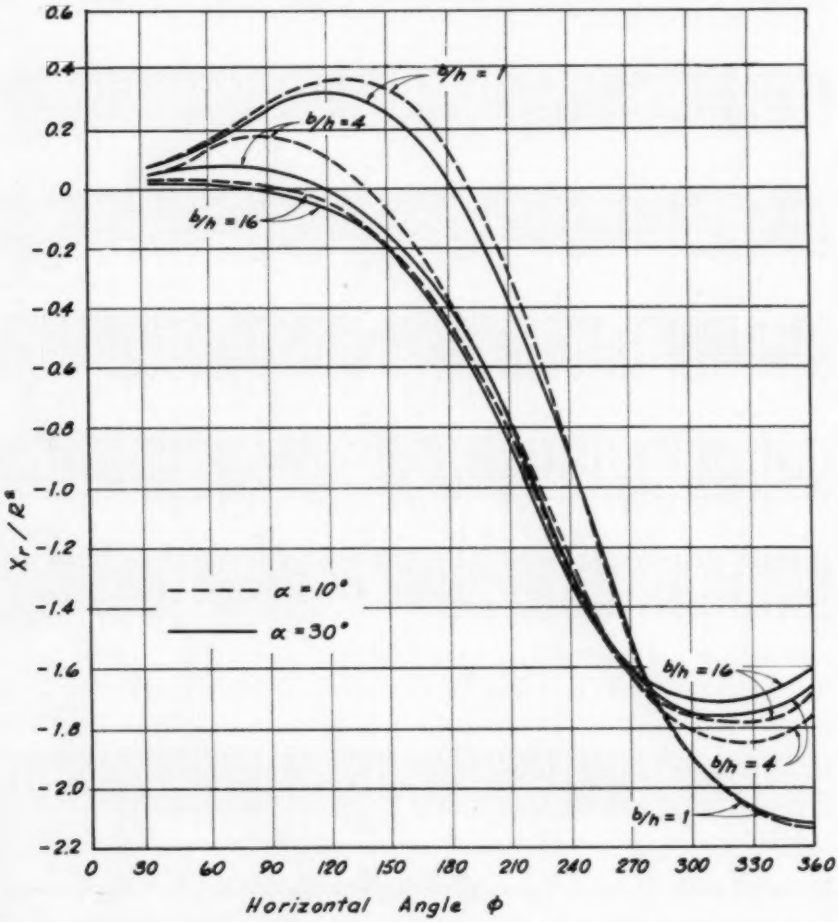

Fig. 5—Values of redundant X_r, for girders of various horizontal angles, ϕ; angles of slope, α; and width-depth ratios b/h

ϕ; the angle of slope α; and the ratios of bending stiffness to torsional stiffness, EI_r/GJ_t and EI_s/GJ_t. The necessary internal machine calculations, for each case, which consisted of the evaluation of the displacements and solution of Eq. (1) and (2) were carried out at fast

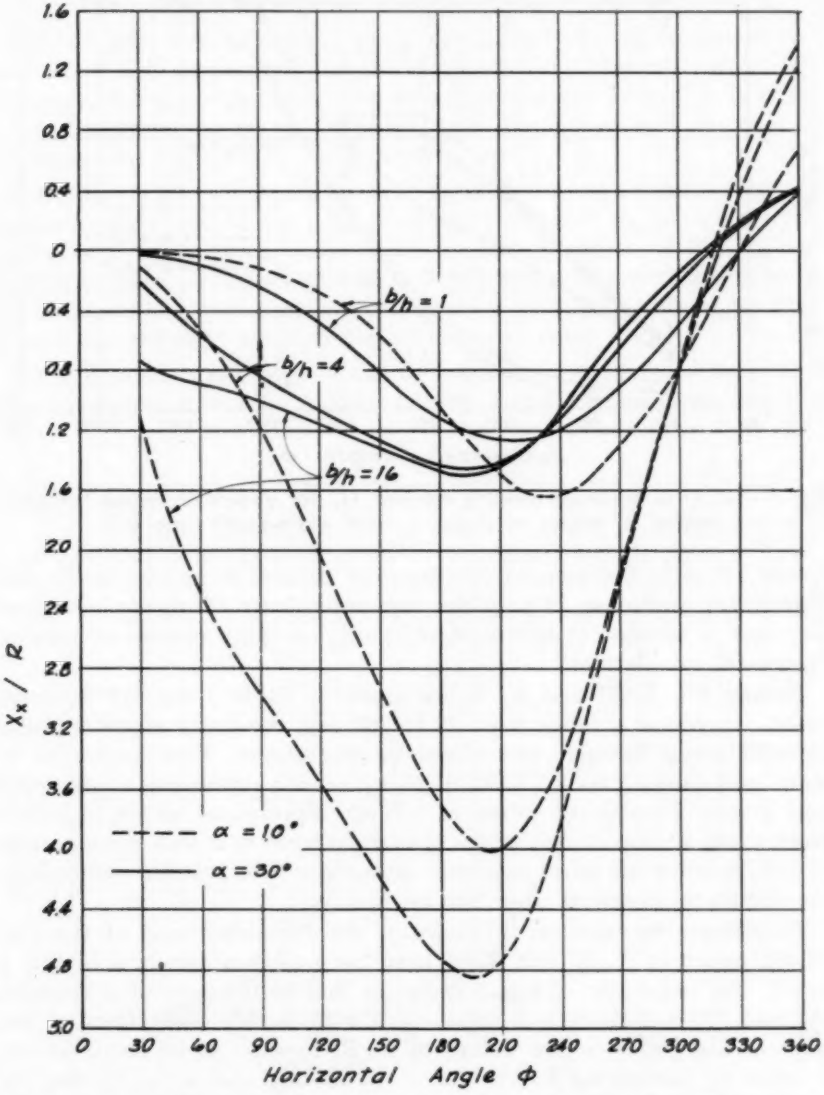

Fig. 6—Values of redundant, X_x, for girders of various horizontal angles, ϕ; angles of slope, α; and width-depth ratios b/h

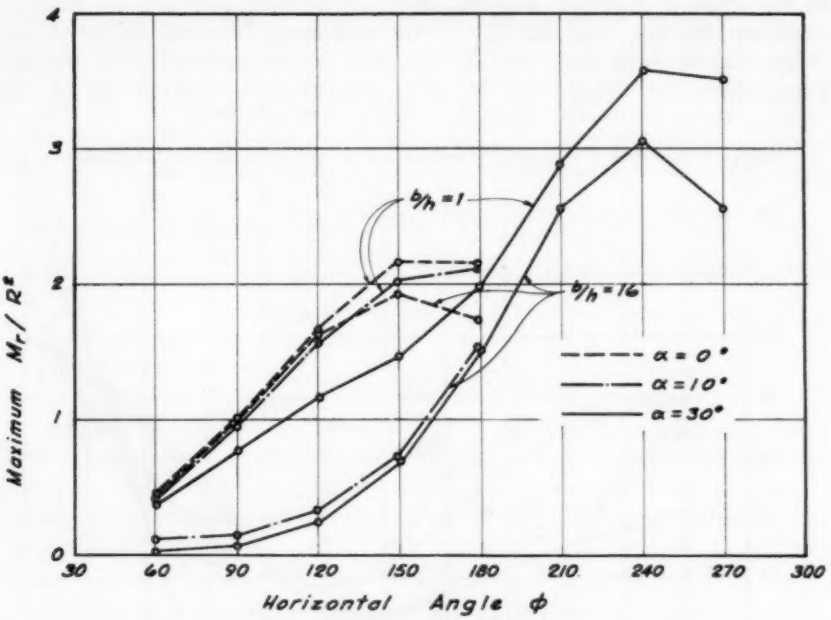

Fig. 7—Values of maximum bending moment, M_r, for girders of various horizontal angles, ϕ; angles of slope, α; and width-depth ratio b/h

speeds. Finally the amount of output in printed form was small consisting, for each case, of only the two redundants. Thus the computer was used to do what it does most efficiently—a large amount of internal numerical calculations.

Results for X_r/R^2 and X_z/R are given in Table 1 for 510 different cases. Angles of ϕ range from 30 to 360 deg, the latter representing a helicoid going through two complete revolutions. Five angles of α were used ranging from 0 to 40 deg. $\alpha = 0$ deg represents a horizontal bow girder. Finally six values of b/h are represented which include a beam cross section of $b/h = 0.5$ at one extreme to a slab cross section of $b/h = 16$ at the other extreme. By proper interpolation redundants for almost all practical cases can be found.

To indicate the general influence of the variables some of the tabulated values of X_r/R^2 and X_z/R have been plotted versus ϕ in Fig. 5 and 6. An inspection of Fig. 5 indicates that in the zone of ϕ between 150 and 270 deg there is a rapid change in X_r/R^2. The effect of the slope of the girder, α, on values of X_r/R^2 appears to be small as can be seen by comparing curves for $\alpha = 10$ deg and $\alpha = 30$ deg for similar b/h ratios. Further it can be noted that the effect of a change in b/h on X_r/R^2 becomes smaller as b/h values get above 4. Fig. 6 defi-

nitely shows that X_x/R is greatly influenced by the angle of slope, α, especially for girders of larger b/h values. It is also apparent that for $\alpha = 30$ deg changing the girder b/h from 4 to 16 has little influence on X_x/R.

MAXIMUM BENDING AND TORSIONAL MOMENTS

The ultimate aim in a structural analysis problem is to obtain the magnitude and distribution of the internal force components in the structure, therefore the moments, shears, and axial forces. It is these values which determine the cross-sectional dimensions and amounts of reinforcement required to resist a given load.

Using Eq. (12), (13), and (14) bending moment and torsional moment diagrams were plotted for a large number of cases to investigate the influence of the various variables on maximum values of M_r, M_t, M_z. These maximum values are plotted in Fig. 7, 8, and 9. Each plotted point was obtained as the maximum value from a completely drawn bending or torsional moment diagram for a particular case.

Some important conclusions can be made from a study of these figures. Attention should be focused on Fig. 7 and 8 since generally it is

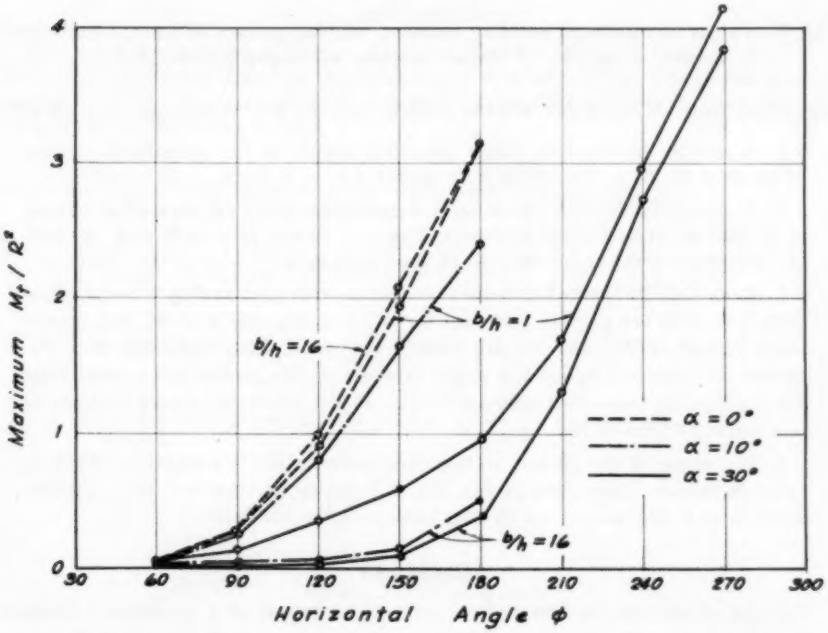

Fig. 8—Values of maximum torsional moment, M_t, for girders of various horizontal angles, ϕ; angle of slope, α; and width-depth ratio, b/h

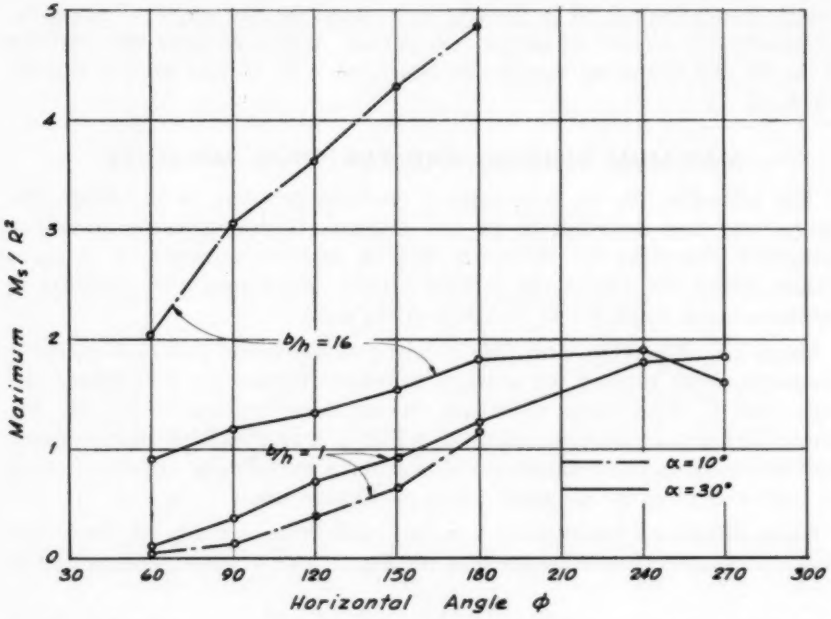

Fig. 9—Values of maximum bending moment, M_s, for girders of various horizontal angles, ϕ; angles of slope, α; and width-depth ratio b/h

the maximum M_r and M_t values which control the design of the girder.

1. A change in the b/h value has little effect on the maximum values of M_r and M_t in a horizontal bow girder ($\alpha = 0$ deg).

2. A change in the b/h value has a tremendous effect on maximum values of M_r and M_t in helicoidal girders having $\alpha = 10$ deg to $\alpha = 30$ deg. M_r *and* M_t are much smaller for $b/h = 16$ than $b/h = 1$.

3. Even though the redundants at midspan indicated in Fig. 6 for girders with $b/h = 16$ are greatly different for $\alpha = 10$ deg and $\alpha = 30$ deg, maximum values of M_r and M_t are nearly the same. This indicates that for girders of high b/h ratios the angle of slope of the girder has a relatively small effect on these two internal forces. Fig. 9, however, shows that there is a marked effect on M_t.

4. The slope of the girder, α, becomes increasingly important as the b/h ratio decreases. Inspection of Fig. 7 and 8 shows that for $b/h = 1$, girders with $\alpha = 0$ deg and $\alpha = 10$ deg behave quite similarly.

SUMMARY

Tabulated values for the redundants at midspan of a uniformly loaded helicoidal girder fixed at its ends have been presented. By proper interpolation values for almost any practical case may be found.

A study of maximum bending and torsional moments in a variety of cases indicates that cross sections with high width-depth ratios should be used in designing helicoidal girders since they carry the applied load in the most efficient manner.

REFERENCES

1. Bergman, V. R., "Helicoidal Staircases of Reinforced Concrete," ACI JOURNAL, V. 28, No. 4, Oct. 1956 (*Proceedings* V. 53), pp. 403-412.

2. Fuchssteiner, W., "Die freitragende Wendeltreppe (Spannungsberechnung und Bewehrung)," *Beton- und Stahlbetonbau* (Berlin), V. 49, No. 11, 1954, pp. 256-258.

3. Gedizli, H. S., Discussion of "Die freitragende Wendeltreppe," *Beton- und Stahlbetonbau* (Berlin), V. 50, No. 9, Sept. 1955, p. 247.

4. Cohen, J. S., "Design of Helical Staircases," *Concrete and Constructional Engineering* (London), V. 50, No. 5, May 1955, pp. 181-194.

5. Holmes, Alan M. C., "Analysis of Helical Beams Under Symmetrical Loading," *Proceedings*, ASCE, Paper No. ST 1437, Nov. 1957, pp. 1437-1–1437-37.

6. Young, Y. F., and Scordelis, A. C., "An Analytical and Experimental Study of Helicoidal Girders," *Proceedings*, ASCE, Paper No. ST 1756, Sept. 1958.

7. Timoshenko, S., and Goodier, J. N., *Theory of Elasticity*, McGraw-Hill Book Co., Inc., New York, 2nd Edition, 1951.

APPENDIX

The formulas presented below give the displacements at the top end of a helicoidal cantilever, fixed at the bottom and free at the top, which has a horizontal angle, ϕ; an angle of slope, α; and a centerline radius, R. See text for definition of remaining terms.

$$\delta_{zw} = \frac{R^4 \tan\alpha \sec\alpha}{EI_r}\left[\sin\phi - \phi\cos\phi - \frac{1}{8}(\sin 2\phi - 2\phi\cos 2\phi)\right]$$

$$+ \frac{R^4 \sec\alpha \sin\alpha}{EI_t}\left\{\left[\frac{\phi}{2} - \sin\phi + \phi\cos\phi - \frac{\sin 2\phi}{4}\right]\cos\alpha\right.$$

$$\left. - \left[2\phi\cos\phi + (\phi^2 - 2)\sin\phi - \frac{1}{8}(\sin 2\phi - 2\phi\cos 2\phi)\right]\tan\alpha\sin\alpha\right\}$$

$$+ \frac{R^4 \sin\alpha}{GJ_t}\left[(3 - \phi^2)\sin\phi - 3\phi\cos\phi - \frac{\phi}{2} + \frac{3}{8}\sin 2\phi - \frac{\phi\cos 2\phi}{4}\right]$$

$$\delta_{rw} = \frac{R^3 \sec\alpha}{EI_r}\left[\frac{\phi}{2} - \sin\phi + \frac{\sin 2\phi}{4}\right]$$

$$+ \frac{R^3 \sin^2\alpha \sec\alpha}{EI_t}\left[\frac{\phi}{2} - \sin\phi - \frac{\sin 2\phi}{4} + \phi\cos\phi\right]$$

$$+ \frac{R^3 \cos\alpha}{GJ_t}\left[\frac{\phi}{2} - \sin\phi - \frac{\sin 2\phi}{4} + \phi\cos\phi\right]$$

$$\delta_{zz} = \frac{R^3 \sec\alpha \tan^2\alpha}{EI_r}\left[\frac{\phi^3}{6} - \left(\frac{\phi^2}{4} - \frac{1}{8}\right)\sin 2\phi - \frac{\phi\cos 2\phi}{4}\right]$$
$$+ \frac{R^3 \sec\alpha}{EI_t}\left\{\left[\frac{\phi}{2} - \frac{\sin 2\phi}{4}\right]\cos^2\alpha + \frac{1}{4}\left[\sin 2\phi - 2\phi\cos 2\phi\right]\sin^2\alpha\right.$$
$$\left. + \left[\frac{\phi^3}{6} + \left(\frac{\phi^2}{4} - \frac{1}{8}\right)\sin 2\phi + \frac{\phi\cos 2\phi}{4}\right]\tan^2\alpha\sin^2\alpha\right\}$$
$$+ \frac{R^3 \sec\alpha \sin^2\alpha}{GJ_t}\left\{\left[\frac{\phi}{2} - \frac{\sin 2\phi}{4}\right] - \frac{1}{4}\left[\sin 2\phi - 2\phi\cos 2\phi\right]\right.$$
$$\left. + \left[\frac{\phi^3}{6} + \left(\frac{\phi^2}{4} - \frac{1}{8}\right)\sin 2\phi + \frac{\phi\cos 2\phi}{4}\right]\right\}$$

$$\delta_{rr} = \frac{R\sec\alpha}{EI_r}\left[\frac{\phi}{2} + \frac{\sin 2\phi}{4}\right] + \frac{R\sec\alpha\sin^2\alpha}{EI_t}\left[\frac{\phi}{2} - \frac{\sin 2\phi}{4}\right]$$
$$+ \frac{R\cos\alpha}{GJ_t}\left[\frac{\phi}{2} - \frac{\sin 2\phi}{4}\right]$$

$$\delta_{r\alpha} = \delta_{\alpha r} = -\frac{R^2\sec\alpha\tan\alpha}{EI_r}\left[\frac{1}{8}\left(\sin 2\phi - 2\phi\cos 2\phi\right)\right]$$
$$+ \frac{R^2\sin\alpha\sec\alpha}{EI_t}\left[\left(\frac{\phi}{2} - \frac{\sin 2\phi}{4}\right)\cos\alpha + \frac{1}{8}\left(\sin 2\phi - 2\phi\cos 2\phi\right)\tan\alpha\sin\alpha\right]$$
$$+ \frac{R^2\sin\alpha}{GJ_t}\left[-\left(\frac{\phi}{2} - \frac{\sin 2\phi}{4}\right) + \frac{1}{8}\left(\sin 2\phi - 2\phi\cos 2\phi\right)\right]$$

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Title No. 56-51

Properties and Uses of High-Magnesia Portland Slag Cement Concretes

By NIKO STUTTERHEIM

Some properties of portland blast furnace slag cements, made from slags having from 13 percent to 20 percent magnesia, are described, in particular those composed of 50 percent slag and 50 percent portland cement clinker plus gypsum. Two ways of blending these constituents are: (a) intergrinding the granulated slag, portland cement clinker, and gypsum in one milling process; (b) grinding portland cement (clinker plus gypsum) and granulated slag separately and then blending them, e.g., in the concrete mixing operation.

Blast furnace slag for this study was derived from three different plants, each of which uses dolomite as fluxing material in its blast furnaces. The composition and properties of the slags and of cements made from them are discussed; the effects of dry and wet grinding of slag, of fineness of grind, and of portland cement content were determined experimentally. Autoclave expansion results were invariably low.

The performance of concrete made with these cements is given in respect to workability, shrinkage, dynamic modulus of elasticity, Poisson's ratio, and compressive and flexural strengths. Values for a portland cement concrete are given for comparison. The results show that the slag cements have good cementitious properties. No correlation between compressive strength and any of the commonly-used hydraulic indices could be found.

Some examples are given of full-scale constructional applications of portland blast furnace slag cements made from high-magnesia slags.

THE USE OF BLAST FURNACE SLAG as a major ingredient of constructional cements is well known, as is evident from reviews of the literature on the subject, [1,2] and its use is increasing not only in Europe, where it was first developed, but also in many other countries.

In some countries limitations have been placed on the composition of the slags which can be used for cement manufacture. One of the stipulations concerns maximum magnesia content. In the case of portland cements the magnesia content is limited to a maximum of about 5 percent of the weight of cement to avoid unsoundness due to periclase, and the evidence for this is well established. [1,3] It has been inferred that similar limitations should apply to slags used in cement, and hence in many

countries the magnesia content of such slags is limited to values of the same order as those applying to portland cement.

This aspect will be discussed only briefly as views on it have been published elsewhere.[4]

A second aspect of the use of high-magnesia slags is that of strength development. It is generally held that the performance of a slag can be predicted from a knowledge of its chemical composition. Although it is believed that, for low contents of magnesia, the latter can be considered as equivalent, weight for weight, to calcium oxide, this is regarded by some as no longer true for values above 8 to 10 percent;[2,5,6] the consensus of opinion is that for higher values the potential hydraulicity of the slag decreases.

RISK OF UNSOUNDNESS DUE TO PERICLASE

If periclase (crystalline magnesia) is present in a constructional cement, it will tend to hydrate slowly when exposed to moisture, the rate of hydration being such that it will continue long after the cement has hardened. Since brucite, the product of hydration, is several times the volume of the parent periclase, disruptive expansion can result, leading to deterioration and, in severe cases, to complete failure. The fact that this condition can occur when new composition ranges or types of cementitious materials are used which contain appreciable amounts of magnesia, must therefore always be taken into account.

Slag intended for cement manufacture (except as raw material for portland cement manufacture, which is not discussed in this paper) is rapidly chilled to convert it to the glassy state. All evidence points to the fact that magnesia dissolved in glass is harmless.[1,3]

Work done by various investigators [4-7] has shown that there is little or no risk of periclase formation in high-magnesia blast furnace slags, and hence they can be used safely.

PERFORMANCE OF CEMENTS MADE OF HIGH-MAGNESIA SLAGS

Experimental results on the performance of cements made with high-magnesia slags, and of concrete made from such cements, have been published by several investigators. Grün[7] concluded that at early ages cements made with high-magnesia slags had similar strengths to those made with low-magnesia slags, but that they did not harden to the same degree at later ages (1-2 years). He also found that they had lower sulphate resistance ($MgSO_4$) than low-magnesia slag cements. Stutterheim and Nurse,[8] using slags with magnesia contents of 15-18 percent in an extension of the work of Parker and Nurse[9] on low-magnesia slags, concluded that magnesia is not as effective as calcium oxide in conferring hydraulicity, which would probably be more evident at early ages. They refer to the possible advantages of finer grinding and of separate grinding.

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Mr. Stutterheim has done much original research work on the use of high-magnesia blast furnace slag in cement, deterioration of concrete due to chemical and natural agencies, and deterioration of concrete due to the effects of aggregates that shrink excessively.

Cirilli and Brisi[10] concluded that even a slag with a magnesia content of 32 percent yielded useful cements; their results show 7- and 28-day compressive strengths of somewhat over 80 percent of those of portland cement for a 60 slag: 40 portland cement mixture.

Appiano[11] gives test results up to 10 years for portland blast furnace cements (60 slag: 40 portland cement) made from slags ranging in magnesia content from 1 to 17 percent. He gives no values for glass content or surface area, but since his finenesses, as determined by sieve residues, were the same, his figures appear to show that although all slags yield fair strengths, magnesia has an adverse effect at all ages.

Mather[12] compared portland blast furnace slag cements, for which the slags had magnesia contents ranging from 2 to 10 percent, but with various ratios of slag to portland cement in his mixtures (most of which were commercial products), so that his results are more difficult to compare. However, he concludes that high-magnesia cement rated well.

Portland blast furnace slag cements made from South African high-magnesia slags

The opinion is generally held that for a slag to be suitable for conversion into a cement it must have a chemical composition within certain limits; in particular, the amount of basic oxides must be high because it has been found that basic slags tend to give better results than acid slags. These general rules have been established for low-magnesia materials, but there is scope for further studies on high-magnesia slags.

The South African iron and steel industry operates its blast furnaces exclusively with dolomitic fluxes, and the resultant slags have magnesia contents ranging from 13 percent to over 20 percent. Interest in the possibilities of making cements from such slags has developed and some information on their properties has been published.[13,14]

The effect of portland cement content on the compressive strength development of mixtures of portland cement and a typical granulated slag of this kind is presented in Fig. 1. The portland cement used was from one batch. Results are averages of three tests and are given for two finenesses of slag, *viz.*, 3200 sq cm per g and 5000 sq cm per g. The two constituents, slag and portland cement, were ground separately and then mixed as part of the concrete mixing operation. The implications of this procedure

are discussed later. The concrete was made of 1 cement (slag + portland) : 2.2 sand : 3.2 stone : 0.45 water by weight.

It will be observed that for most ages and up to 40 percent portland cement content, there is a roughly linear relationship between strength and percentage portland cement. Above 40 percent portland cement, the strengths at the later ages are more nearly equal to that for portland cement concrete, though still lower at early ages, particularly for the more coarsely ground slag.

Hence, to achieve strengths at 28 days of the order of those of portland cement, it is necessary to use at least 40 percent portland cement as activator.

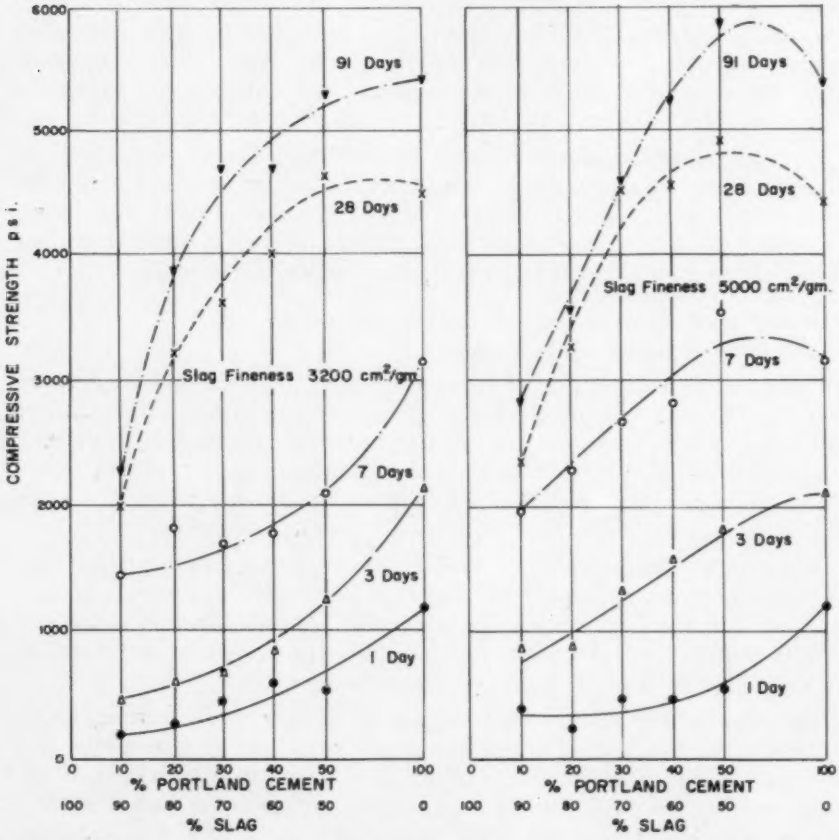

Fig. 1—Effect of portland cement content on compressive strength of concrete made with finely ground slag (two finenesses)

Effect of fineness and of wet grinding

The conventional procedure for making portland blast furnace slag cement is to grind portland cement clinker, granulated slag, and gypsum together, in which case there is no control over the relative finenesses of the two major constituents, and preferential grinding of the softer material will take place; this is generally the portland cement fraction. For most of the work reported in this paper the materials were ground separately, to be able to obtain information on the relative finenesses of the constituents.

The effect of fineness of the slag on the strength quality of portland blast furnace slag cement is shown in Fig. 2, the curves being based on averages of three determinations. The concrete was made of 1 cement : 2.2 sand : 3.2 stone : 0.45 water by weight. As the slag was more finely ground, its contribution to strength increased, particularly at later ages; 1-day strength was not materially affected by fineness of the slag. Probably the most effective way of increasing early strength development of Portland blast furnace slag cements is by using a finely ground portland cement, e.g., a high-early-strength cement, with the slag.

A study was made to see whether there was an advantage in using wet grinding for South African slags. At the same time comparison tests were made with slag ground dry, but separately from portland cement.

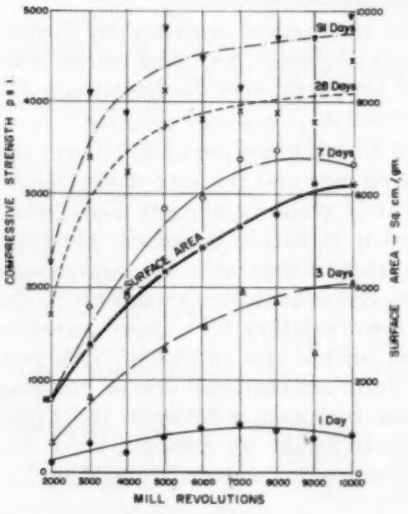

Fig. 2—Effect of fineness of slag (expressed in mill revolutions) on strength of concrete. Activator 25 percent portland cement

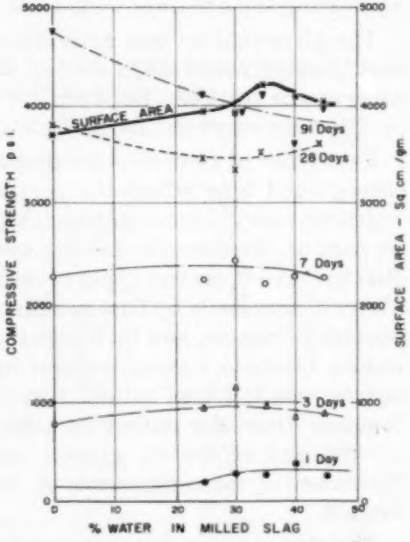

Fig. 3—Comparison of strengths of concrete made from dry-ground and wet-ground slag. Activator 25 percent portland cement

In Fig. 3 strength values are plotted for slag ground dry and wet with various water contents. All samples were ground for the same number of mill revolutions. The concrete was made of 1 cement : 2.2 sand : 3.2 stone : 0.45 water by weight; the curves are based on triplicate determinations. Wet grinding gave a greater fineness than dry grinding, provided optimum water content was used. However, no advantage was found in using wet grinding from the point of view of strength development.

PROPERTIES OF CONCRETES MADE WITH HIGH-MAGNESIA SLAGS-PORTLAND CEMENT MIXTURES

Having established that these high-magnesia slags had promising hydraulic qualities, a systematic investigation was started on the more important properties of portland blast furnace slag cements, and on concrete made with them. Some of the findings available to date are given below.

Details of slags and of cements made from them

The slag used was derived from three different plants. Ten weekly samples were obtained from each of the Pretoria and Vanderbijl plants of South Africa Iron and Steel Industrial Corp., and one sample from African Metals Corp., Newcastle, Natal.

The magnesia contents of samples ranged from 13 to 20 percent. Slag P was derived from a blast furnace operating on sintered iron ore produced by heating the ore fines with low-magnesia limestone.

The glass content was determined by the method described by Parker and Nurse [11] modified in that an integrating stage was used rather than an eyepiece graticule. Between 300 and 400 particles of the fractions − 170 + 270 were surveyed for each determination.

Two types of cement were prepared for each sample of slag: one, the interground type where the portland cement and the slag were ground together, and the other in which separately ground materials were mixed as part of the concrete mixing operation. It should be added, however, that to make these two types of cement more comparable, the interground material was made by first grinding the two constituents separately to the required fineness, and then grinding them together for a short period to ensure intimate mixing without much further size reduction. This procedure was followed rather than the more conventional one of grinding together from the outset, as otherwise comparison between the interground and separately ground materials would be difficult, since the finenesses of the components of the interground materials would be unknown.

The slag samples were ground by the dry process to a fineness of 3550 ± 100 sq cm per g (Blaine), and stored in sealed drums till required. The portland cement used both for mixing with the ground slag and for control purposes was obtained in one batch from a single spout of a com-

mercial cement packer and stored in sealed bins; it was of ordinary grade and has the code letters HPC in this paper.

The compositions of the slags and the properties of the experimental cements are given in Table 1. Information on portland cement HPC is included for comparison.

All individual autoclave expansion values for the slag were below 0.2 percent, even though the portland cement with which they were mixed to cast the autoclave specimens, had an expansion of 5.6 percent, no doubt largely due to free CaO.

Properties of concretes made with experimental cements

All concrete testing was done under controlled conditions with standardized procedures to reduce variations. The specimen casting program was arranged to ensure a random distribution of casting dates for repeat specimens. The temperature in the laboratories was controlled at 20 C ± 1 deg. All curing was done in a fog room at 20 C and 100 percent relative humidity with excess moisture in a fine continuous mist.

In Tables 2 and 3 the average results for various properties of concretes made from these cements are given. The portland blast furnace slag cements are identified by code letter; in addition there is added either the letter G, signifying that the portland cement and the slag were interground, or M, indicating that mixing of these constituents occurred as part of the concrete mixing operation.

TABLE 1—DETAILS OF BLAST FURNACE SLAGS USED FOR CEMENT AND CONCRETE STUDIES (AVERAGE VALUES)

Constituent or property		V*	P†	N‡	HPC§
Slag:					
SiO_2, percent		32.8	32.8	33.2	—
Al_2O_3, percent		14.3	11.2	18.2	—
CaO, percent		30.3	36.7	28.2	—
MgO, percent		19.5	14.0	18.5	—
S, percent		1.0	0.7	1.4	—
MnO, percent		0.9	0.8	0.2	—
FeO, percent		0.6	2.5	0.6	—
Bulk density, g per liter		910	1190	510	—
Specific gravity		2.86	2.93	2.84	—
Glass content, percent		95	90	99	—
Surface area, sq cm per g		3590	3490	3560	—
Cement:					
Surface area, sq cm per g		3410	3370	3380	3140
Setting time, min	Initial	2:40	2:30	3:00	2:10
	Final	4:20	4:10	4:05	3:45
**Mortar compressive	3 day	2260	2360	2830	3660
strength, psi	7 day	4430	4610	5830	5250
Autoclave expansion, percent		0.11	0.11	0.09	5.6

*Slags from Vanderbijl plant of South African Iron and Steel Industrial Corp.
†Slags from Pretoria plant of South African Iron and Steel Industrial Corp.
‡Slag from Newcastle plant of African Metals Corp.
§Normal portland cement control.
**Mortar for the compression test was 1 cement : 3 sand : 0.4 water by weight (British Standard 146:1958).

For Cements VG, VM, PG, and PM, the figures in Table 2 are averages of between 20 and 60 tests, except for the compressive strength results which are averages of between 40 and 120 tests. For Cements NG, NM, and HPC the figures are averages of 2 to 6 tests, except the compressive strength figures which are averages of 4 to 12 tests.

The workability, as determined by slump and compaction factor is virtually identical for all cements. The VeeBee results show a slightly higher workability for the portland cement control than for the portland blast furnace slag cements.

It appears that these portland blast furnace slag cements have a lower shrinkage than the portland cement. The results are rather variable, as figures for shrinkage tend to be, and therefore more results are required before a statistically valid conclusion can be drawn.

TABLE 2—PROPERTIES OF CONCRETES MADE WITH PORTLAND BLAST FURNACE SLAG CEMENTS, AND WITH A PORTLAND CEMENT CONTROL*

	VG†	VM‡	PG†	PM‡	NG†	NM‡	HPC
Slump, in.§	3/8	3/8	1/2	1/2	1/4	1/4	3/8
Compaction factor§	0.84	0.83	0.84	0.84	0.82	0.82	0.84
VeeBee degrees**	12.6	12.8	12.5	11.9	13.4	13.4	13.6
Shrinkage, percent§	0.016	0.024	0.019	0.026	0.043	0.023	0.035
Modulus of rupture, psi§							
1 day	100	90	90	80	150	100	200
3 day	350	350	350	400	440	420	550
7 day	600	580	590	630	590	750	720
28 day	910	940	890	900	950	880	850
91 day	1030	990	960	980	980	970	940
Compressive strength, psi§							
1 day	970	750	810	690	1090	920	1480
3 day	2250	2220	2180	2220	2560	2630	2670
7 day	3920	3990	4170	3810	4600	4620	4620
28 day	7070	7430	6720	6870	6400	6340	6750
91 day	8550	9000	8380	8130	8540	8430	7750

*Concrete mix is 1 cement : 2.5 sand : 3.5 stone : 0.50 water by weight, and moist cured.
†G indicates interground cement.
‡M indicates separately ground portland cement and slag that was mixed in the concrete mixer.
§According to British Standard 1881:1952.
**Swedish vibrated slump cone consistency test.

TABLE 3 — AVERAGE DYNAMIC MODULUS OF ELASTICITIES (*E*) AND POISSON'S RATIOS FOR PORTLAND BLAST FURNACE CEMENT CONCRETES AND FOR PORTLAND CEMENT CONTROL*

Cement	VG	VM	PG	PM	NG	NM	HPC
$E \times 10^{-4}$ psi:							
1 day	2.79	2.29	2.51	2.12	3.28	3.06	4.03
3 day	5.33	5.38	5.31	5.38	5.77	5.95	5.81
7 day	6.89	6.96	6.78	6.88	7.17	7.30	6.94
28 day	8.02	8.17	7.84	7.76	7.90	7.98	8.05
91 day	8.60	8.60	8.46	8.18	8.85	8.40	8.54
Poisson's ratio:							
1 day	0.36	0.41	0.40	0.41	0.38	0.38	0.30
3 day	0.34	0.33	0.35	0.35	0.31	0.33	0.36
7 day	0.29	0.30	0.31	0.30	0.28	0.28	0.30
28 day	0.28	0.29	0.29	0.30	0.23	0.27	0.28
91 day	0.28	0.28	0.27	0.30	0.28	0.27	0.27

*Concrete mix is 1 cement : 2.5 sand (quartz) : 3.5 stone (norite) : 0.50 water by weight, moist cured.

The results for modulus of rupture are similar for the various portland blast furnace slag cements. As a group they differ from those for the portland cement control in being lower at ages of 1, 3, and 7 days; thereafter the values surpass those of the control cement. These trends can be seen clearly in Fig. 4.

As a typical example, average results for compressive strength of concretes made from slag cements are plotted in Fig. 5, for both interground and separately mixed cements.

There was no great difference between results for portland blast furnace slag cements when interground and when separately mixed, the latter material giving somewhat higher strengths at later ages, though the difference may not be significant.

The strengths for concrete made from the portland blast furnace slag cement are below those for the portland cement control but only up to about 16 days; thereafter the strengths are higher than for the portland cement, the age-strength curves becoming increasingly divergent with time.

It is clear therefore that notwithstanding the high magnesia content, these slags have good hydraulic properties.

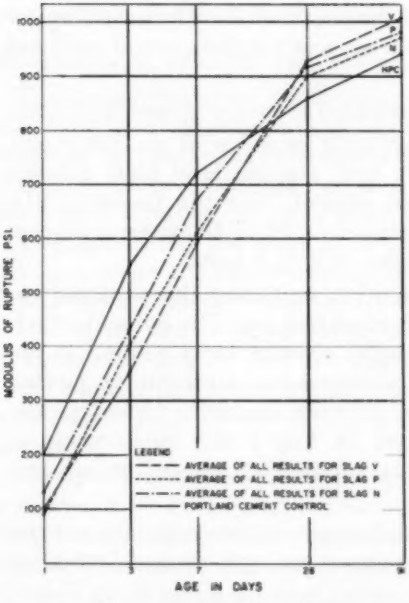

Fig. 4—Average modulus of rupture versus age for portland blast furnace slag cement concretes and for portland cement concretes

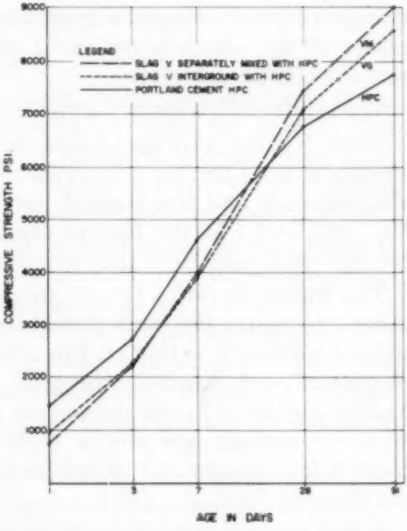

Fig. 5—Average compressive strengths versus age for concretes made with portland blast furnace slag Cements VG and VM. Comparison curve for portland cement is also given (HPC)

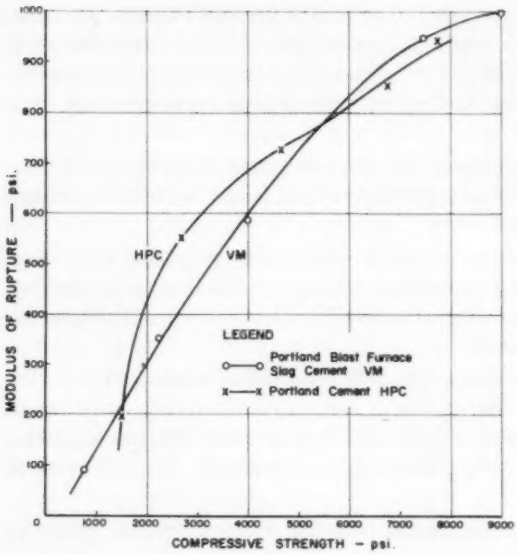

Fig. 6 — Relationship between modulus of rupture and compressive strength for a portland blast furnace slag cement (VM) and a portland cement (HPC)

In Fig. 6 the relationships between modulus of rupture and compressive strength for concrete made from one of the portland blast furnace slag cements (VM), which is typical of the series, and for the control portland cement (HPC) are given.

The relationships clearly differ appreciably for the two types of cement.

Table 3 gives average values for dynamic modulus of elasticity and Poisson's ratio for the concretes made with the portland blast furnace slag cements and the control portland cement. For the Cements VG, VM, PG, and PM the figures are averages of 20 to 60 determinations; for NG, NM, and HPC they are averages of 2 to 6 tests.

The Poisson's ratios for all these cements including the portland cement, are nearly the same at each respective test age. The dynamic modulus of elasticity values on the other hand appears to be related to the respective compressive strengths. If compressive strength is plotted against dynamic *E*, the curves for the different cements, including the portland cement, are nearly coincident. In Fig. 7 this relationship is plotted for Cement VG, which is typical of the slag cement group, and for Cement HPC.

It will be seen that although the modulus-age relationships are not the same for the various cements, the compressive strength-dynamic modulus relationships are closely similar.

The results given in Tables 2 and 3 were all derived from concretes that had been moist cured at constant temperature until tested. It is probable that with curtailed curing the concretes would have different properties

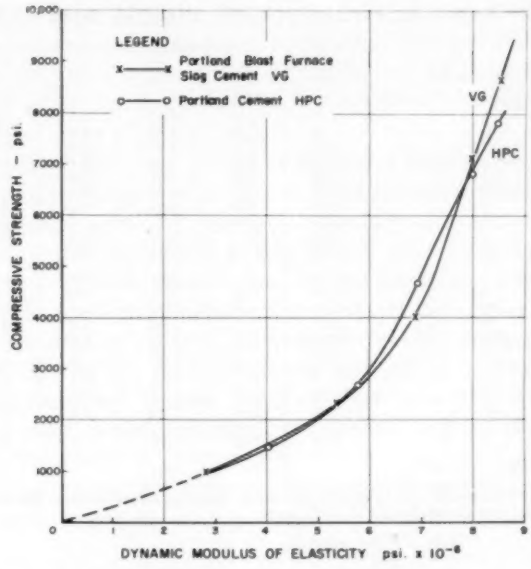

Fig. 7 — Relationship between compressive strength and dynamic modulus of elasticity for concretes made with Cements VG and HPC

due to interrupted hydration, the effects being more pronounced for the slag cement concretes than for portland cement concrete.

Correlation of strength and composition

Various hydraulicity indices are in current use for low-magnesia slags, and a number of authors[1,2,8,9,15] have expressed views on criteria that might be applied to high-magnesia slags. Some of those which have been cast in mathematical form are given in Table 4. Where CaO is given in brackets it refers to the value after deduction of CaO combined as CaS.

The indices for the slags in the series under discussion are listed in columns under the corresponding formula number. In addition the average 28-day and 91-day compressive strengths are given.

One of the uncontrolled variables in previous work has been fineness of the clinker and the slag only the fineness of the mixture being known. It is rather to be expected that this uncontrolled but important variable would make difficult any correlations between strength and compositional factors.

However, notwithstanding the control over slag and cement fineness achieved in this study, no correlation was found between any of the hydraulic indices and the performance of the various samples of Slags V, P, and N. There is also no evidence to indicate that better correlation exists if the MgO is given a value lower than the CaO in the formulas.

It appears therefore that the formulas used so extensively for predicting hydraulicity of granulated slags have serious limitations. Perhaps it is too much to expect that there should be a linear relationship between oxide

TABLE 4—HYDRAULICITY INDICES AND COMPRESSIVE STRENGTH

Formulas	Hydraulicity indices (1)	(2)	(3)	(4)	(5)	Compressive strength, psi 28 day	91 day
Slag:							
V 1	1.27	1.85	1.58	6.7	0.89	6380	7960
2	1.25	1.79	1.53	4.4	0.86	6960	9630
3	1.19	1.78	1.53	4.3	0.94	7000	8540
4	1.25	1.80	1.56	5.4	0.93	7080	9270
5	1.26	1.88	1.61	7.4	0.94	7450	8870
6	1.27	1.94	1.67	9.8	0.95	7730	8590
7	1.25	1.93	1.65	9.6	0.94	6970	8030
8	1.27	1.98	1.73	11.2	0.95	7370	8680
9	1.29	2.11	1.85	15.3	0.94	6690	7690
10	1.27	2.13	1.81	14.3	0.92	7080	8220
P 1	1.35	1.89	1.69	10.2	30.91	7220	9190
2	1.34	1.89	1.67	9.9	0.89	6890	8570
3	1.40	1.96	1.75	12.9	0.91	6540	6990
4	1.27	1.77	1.56	6.6	0.85	6400	8380
5	1.26	1.75	1.55	5.9	0.75	6310	7500
6	1.28	1.79	1.59	7.1	0.93	6970	9410
7	1.35	1.89	1.66	10.2	0.97	6410	8320
8	1.37	1.91	1.71	11.2	0.97	6190	7980
9	1.33	1.88	1.72	10.3	0.89	6990	8760
10	1.30	1.85	1.69	9.2	0.92	7300	8690
N 1	1.15	1.93	1.71	11.8	0.91	6490	8540
HPC	—	—	—	—	—	6750	7750

*Formulas (1) through (5) were used in determining the above hydraulicity index numbers and are given below as follows:

(1) $$\frac{(CaO) + MgO + Al_2O_3}{SiO_2} \geqq 1$$

(2) $$\frac{(CaO) + MgO + 1/3\ Al_2O_3}{SiO_2 + 2/3\ Al_2O_3} \geqq 1$$

(3) $$\frac{CaO + CaS + 1/2\ MgO + Al_2O_3}{SiO_2 + MnO} < 1.5 \text{ medium; } 1.5\text{-}1.9 \text{ good; } > 1.9 \text{ excellent}^2$$

(4) $$20 + CaO + Al_2O_3 + 1/2\ MgO - 2SiO_2 < 12 \text{ medium; } 12\text{-}16 \text{ good; } > 16 \text{ excellent}^{15}$$

(5) $$S = 0.38\ G\ (M - 0.72) + 75 \qquad \text{(Ref. 9)}$$

where S = percentage strength of portland cement concrete (90 day)
G = glass content of granulate
M = modulus according to formula (1)

composition and hydraulicity. In this respect the work of Solacolu, [16] which has shown much more complex relationships, justifies further study.

SOME PRACTICAL APPLICATIONS OF PORTLAND BLAST FURNACE CEMENT MADE FROM HIGH-MAGNESIA SLAGS

Since the experimental work described yielded promising results, it was decided to carry out a pilot study of the manufacture of this type of cement and to use the product for a range of different types of construction, to establish the reaction of engineers, contractors, and construction workers, to its use.

Sections of irrigation canal

The Irrigation Department was engaged in the construction of an irrigation dam with its canals in 1952-53 when this experimental project was developed. About 60 tons of slag having a magnesia content averaging 19

percent, were ground to a fineness of about 5000 sq cm per g, and used for portions of one of the canals as well as for a bridge and a superpassage. It was combined with portland cement in the proportions of 70 slag to 30 portland cement, the mixing being part of the normal concrete mixing operation on the site.

Apart from instructions about the proportions of portland cement and slag to be employed, the same procedure and control were maintained on the job as for sections made with portland cement alone. It was reported that the workability of the resulting concrete was better than that for concrete made with ordinary portland cement. Setting and initial hardening were somewhat slower, as a result of which it was sometimes necessary to do the finishing operations in the late afternoon or early evening, instead of being able to finish at the end of the normal working day. Apart from this and the somewhat lighter color of the concrete, no differences in the performance of the concrete, compared to portland cement, were observed or reported.

Fig. 8 shows a section of canal, part of which was constructed with portland blast furnace slag cement concrete and part with portland cement concrete.

Floor for a carriage shed for the Railways Administration

One bay of the floor of a railway carriage shed was constructed in 1953 with a mixture of 70 percent finely ground slag and 30 percent portland cement. In this case early strength was not a requirement and the material was found to perform as well as portland cement.

Low-cost housing

Early in 1953 a series of different types of low-cost houses was constructed as part of a project to determine means of reducing housing costs.

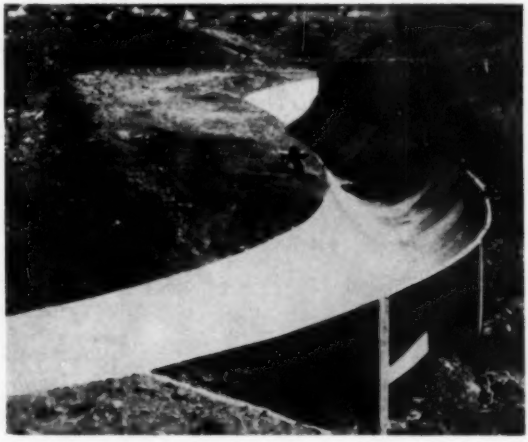

Fig. 8 — Irrigation canal partly constructed with experimental portland blast furnace slag cement concrete in 1953

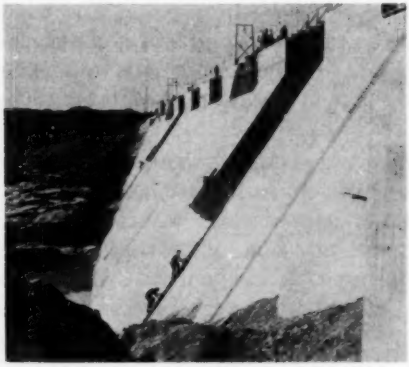

Fig. 9 — Allemanskraal Dam — downstream view during construction

Arrangements were made to utilize a mixture of 70 parts finely ground slag to 30 parts portland cement by weight as the cementing agent for precast concrete elements, concrete block and slabs, as well as for foundations, flooring, mortar, and plaster work. In all cases the mixing of the two constituents was part of the concrete mixing operation. Apart from the rather better workability and the slower initial rate of hardening, no differences in the performance of this type of cement, compared to ordinary portland cement, were observed, an observation confirmed after 5 years of service.

Full-scale production of portland blast furnace slag cement

The pilot stage results were sufficiently encouraging to justify commercial production of cements based on these high-magnesia slags. Details of the experimental findings were communicated to the portland cement industry as a result of which several manufacturers decided to produce portland blast furnace slag cement.

Initial experiments on full-scale milling showed that the granulated slag was harder to grind than portland cement clinker, and that therefore mill output for a particular fineness was lower than with clinker. Since, in general, granulated slag has to be ground very finely, preferably more finely than portland cement, to compensate for its rather slower reaction with water, this was initially regarded as a disability. However, the gran-

Fig. 10—Canal of Sand River irrigation scheme

Fig. 11—Detail of siphon construction

ulated slag is available at much lower cost per ton than portland cement clinker.

Two methods of producing cements from granulated slag are now in operation on an industrial scale in South Africa. One involves the conventional intergrinding of slag, portland cement clinker, and gypsum, while in the other, slag after drying is milled to a fineness generally in excess of 3500 sq cm per g and sold in this form for admixture with portland cement on the job.

The use of both interground and separately ground types of portland blast furnace slag cement is increasing in South Africa, and it is employed for most types of construction for which portland cement is used.

APPLICATIONS OF HIGH-MAGNESIA SLAG CEMENT

Irrigation works

Two dams have been constructed with the interground type of portland blast furnace slag cement. One, completed in 1959, is the Allemanskraal Dam on the Sand River, Orange Free State. This is a gravity section dam with a maximum crest height of 108 ft, a 700 ft long spillway section, and a total concrete volume of 200,000 cu yd. Fig. 9 shows a view of this dam.

The 80 miles of canal for this system were also constructed of portland blast furnace slag cement concrete. Fig. 10 shows a section of this canal during construction.

Auxiliary structures like bridges, wiers, and inverted siphons were made with the same type of cement. Fig. 11 shows a 6700 ft long twin pipe siphon with a 4 ft 6 in. internal diameter.

The second dam (Fig. 12) is the Roodeplaat Dam on the Pienaars River, Transvaal, started in 1956 and completed in 1959. This variable radius arch structure, 193 ft to the spillway, has a concrete volume of about 100,000 cu yd. The cement used was interground portland blast furnace cement.

Reinforced concrete frame construction

Slower initial hardening makes portland blast furnace cements less satisfactory than ordinary portland cements, although in time the ulti-

Fig. 12—Upstream view of Roodeplaat Dam, Transvaal

mate strength may be quite adequate, for certain types of construction. For example, framed structures require high early strength so as to allow early stripping of formwork, particularly of columns, which is of economic importance. In the case of interground portland blast furnace slag cements, early strength can be improved by grinding more finely, thereby converting the portland cement fraction to a high-early-strength cement. A somewhat higher gypsum content may then also improve performance at early ages.

In the case of separately ground slag, the same effect can be achieved by mixing it with a high-early-strength portland cement.

This procedure was adopted in a multistory reinforced concrete frame building (Fig. 13). High-early-strength portland cement and finely ground slag were delivered to the site in bulk and proportioned as part of the concrete weigh-batching operation. Column forms were stripped within 24 hr, as with ordinary portland cement concrete.

Reinforced concrete chimney

Because of an extension to the power station of the Sasol oil-from-coal industry in the northern Orange Free State, a 250 ft concrete chimney was required (Fig. 14). It was decided to use finely ground slag and high-early-strength portland cement, proportioned in equal quantities by weight and mixed during the concrete mixing operation. Construction was by slip-form.

IMPLICATIONS OF USING SEPARATELY GROUND SLAG AS A CEMENT CONSTITUENT

Reference has been made in this paper to separate grinding of slag as one means of producing an ingredient for use in cement. The more usual procedure of grinding granulated slag and clinker together, leads to differential grinding of the softer clinker; this can have advantages, particularly if improved early strength is the aim. However, since the grindability of both the clinker and the slag are in general anything but con-

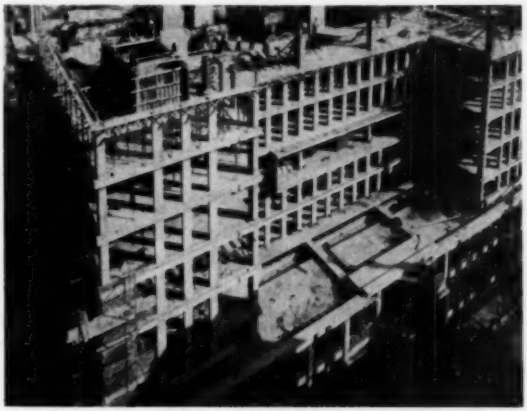

Fig. 13 — Reinforced concrete frame structure of New Stock Exchange, Johannesburg

Photo by permission of Roberts Construction Co.

stant, the fineness of these constituents will vary quite appreciably from time to time, even though the combined fineness may be kept constant. This will tend to introduce variations in quality.

There is an advantage, therefore, in separate grinding of the constituents and their subsequent blending, either as a factory process or a job operation.

If mixing is done on the job, it is most important to exert control to ensure that the proportions of portland cement and slag are correct.

The results presented in this paper show that there is no material difference between the performance of an interground portland blast furnace slag cement and that of a combination of separately ground portland cement and slag mixed as part of the concrete mixing operation, all other factors being equal.

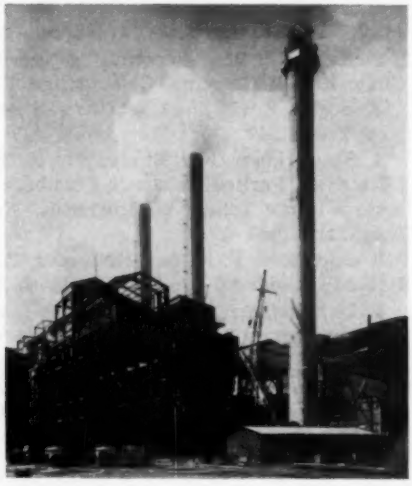

Fig. 14—Chimney at Sasol oil-from-coal plant

Photo by permission of SASOL and Christiani and Nielsen

The question could be formulated in many ways, and depends on the criteria which are applied. If the major requirement of a cement is strength, then presumably the criterion is how to achieve maximum strength per unit cost or minimum cost per unit of strength.

CONCLUSION

The work on cements made with South African high-magnesia blast furnace slags, and concretes made with them, has demonstrated that a sound constructional cement can be made with such slags in combination with portland cement, yielding material which has properties not unlike those of portland cement itself; the main difference of practical concern lies in a somewhat lower initial strength development.

It is recommended that high-magnesia slag intended for use in cement be checked for soundness by ASTM autoclave test.

As will be reported in a later paper, it has been demonstrated that by judicious combination with more finely ground portland cements, it is possible to increase the strength at early ages to a point where the values are comparable to those for ordinary portland cements.

ACKNOWLEDGMENT

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REFERENCES

1. Lea, F. M., and Desch, C. H., *The Chemistry of Cement and Concrete*, Arnold Publishing Co., London, 2nd Edition, 1956.

2. Keil, F., "Slag Cements," *Proceedings*, Third International Symposium on Chemistry of Cements, Cement and Concrete Association, London, 1952.

3. Bogue, R. H., *The Chemistry of Portland Cement*, Rheinhold Publishing Co., New York, 1947.

4. Stutterheim, N., "Etudes sur le Systeme Quarternaire CaO-Al_2O_3-SiO_2MgO Portant en Particulier sur la Possibilite de Fabriquer du Ciment de Haut Fourneau a Haute Teneur en Magnesie," *Revue des Materiaux* (Paris), No. 455-456, Aug.-Sept. 1953.

5. Budnikov, P. P., and Koupreva, Z. S., "Cements from Magnesia-Rich Slag," *Doklady Akademii Nauk SSSR*, V. 65, No. 5, 1949.

6. Dubuisson, A., "Apercu sur les Liants Hydrauliques Riches en MgO," *Revue des Materiaux* (Paris), Edition C., No. 412, Jan. 1950, pp. 8-15.

7. Grün, R., "Zemente mit Hochofenschlacken-Zusatz," *Proceedings*, Association International des Materials Congress, Zurich, Sept. 1931, pp. 778-845.

8. Stutterheim, N., and Nurse, R. W., "Experimental Blast-Furnace Cement Incorporating High-Magnesia Slag," *Magazine of Concrete Research* (London), V. 3, No. 9, Mar. 1952, pp. 101-106.

9. Parker, T. W., and Nurse, R. W., "Investigations on Granulated Blast Furnace Slags for the Manufacture of Portland Blast Furnace Cement, *National Building Studies*, Her Majesty's Stationary Office, London, 1949.

10. Cirilli, V., and Brisi, C., "Researches Concerning the Utilization of Slags with a High-Magnesia Content in the Binder Industry," *L'Industria Italiana del Cementa* (Rome), Sept. 1955.

11. Appiano, M., "Limits of Magnesia Content in Blast Furnace Cement," *Il Cemento* (Milan), V. 52, No. 2, Feb. 1956.

12. Mather, B., "Laboratory Tests of Portland Blast Furnace Cements," ACI JOURNAL, V. 29, No. 3, Sept. 1957 (*Proceedings* V. 54), pp. 205-232.

13. Davies, R. J., "Portland Blast Furnace Cement," *South African Industrial Chemist* (Johannesburg), Nov. 1957, p. 232.

14. Mills, R. H., "A Preliminary Investigation of the Engineering Properties of Concrete Incorporating High-Magnesia Blast Furnace Slag," *Transactions*, South African Institution of Civil Engineers, Sept. 1959, pp. 250-257.

15. De Langavant, Cleret, "Considerations Theoretiques sur la Nature du Laitier de Cimenterie," *Revue des Materiaux* (Paris), No. 402 and No. 403, 1949.

16. Solacolu, S., "Die Bedeutung der thermischen Gleichgewichte des Systems MgO-CaO-Al_2O_3-SiO_2 für das Schmelzen und Granulieren der Hochofenschlacken," *Zement-Kalk-Gips* (Wiesbaden), V. 11, No. 4, Apr. 1958, pp. 125-137.

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Title No. 56-52

Utility Poles of Reinforced and Prestressed Pipe

By E. WOLMAN

Design of utility poles of circular section constructed of reinforced concrete and prestressed pipe, which are subjected to relatively high bending moments and to negligible axial forces and shear stresses, is considered. Forces acting on simple, corner, and other poles are considered, as well as how to distribute the reinforcement to obtain best results. Design formulas are suggested.

■ POLES OR PYLONS SUPPORTING OVERHEAD utility lines are subdivided as follows:

1. "In-between" poles on a straight line, subsequently called "simple poles"
2. End poles
3. Corner poles
4. Anchorage poles

HORIZONTAL FORCES ACTING ON REINFORCED CONCRETE POLES

Simple poles should be equidistant from each other to balance the tension on both sides. The horizontal forces are wind pressure normal to wires (or their enlarged sections due to snow and ice) and tension in case of a one-sided rupture of wires. As a rule, these poles are designed for wind pressure as the main horizontal force, with an allowance in reinforcement for the possible rupture of a cable or two out of a great number.

End poles usually contain anchorages in their lower portions and are designed mainly for one-sided pull in their upper portions.

Corner poles, such as are used at street corners, often cannot be anchored and are designed for the resulting pull of two lines on their full height.

Anchorage poles are designed for one-sided traction.

In all cases, although reinforced concrete pipe used as utility poles are subjected to axial forces and to bending moments, their design usually takes into account only the bending moments, as the axial forces due to dead load, wires, and snow load are of minor importance.* (In

*See Sachnowsky, *Stahlbetonkonstruktionen*, VEB Verlag Technik, 1956 (translated from Russian).

E. Wolman, consulting structural engineer, Tel-Aviv, Israel, became interested in concrete utility poles when consulted on this subject by some manufacturers of reinforced concrete pipe. He holds a number of patents in the structural field, including prestressed concrete pipe. Previously chief quantity surveyor for bridges and culverts with the Israel Railways, most of his recent work has been concerned with industrial buildings.

steel pole design, the axial forces are taken into account because of the buckling of slender sections.)

The design of reinforced concrete poles should also take into account the bending moments encountered during transportation and erection.

The allowable stresses in this paper are those of ACI Code for flexure or similar values.

DISTRIBUTION OF REINFORCEMENT

The following three methods of distributing reinforcement are dealt with:

1. Reinforcement equally distributed around the circumference. This can be used for any kind of pole.

2. Reinforcement concentrated at two opposite sides. This can be used for simple poles against moments in the main direction, and for end and anchorage poles, provided that some reinforcement distributed according to Method No. 1 is added against secondary moments. This arrangement requires special marking of the poles for proper orientation during erection.

3. Reinforcement distributed in accordance with a cosine function. This is a refinement of Method No. 1. It can be used for any kind of pole and it also requires marking for orientation.

The following notation will be used (other terms are explained where they are used in the text):

D = outside diameter of pipe
t = wall thickness
r = medial radius
f_c = permissible stress in concrete (compression)
f_s = permissible stress in reinforcement (tension)
f_s' = permissible stress in reinforcement (compression)
Q = external force
P = total internal force (P_c — for concrete; P_{As} — for reinforcement in tension; $P_{A's}$ — for reinforcement in compression)
a_s = area of reinforcement per unit length of circumference
A_s = total tensile reinforcement
A_s' = total compressive reinforcement
A_T = sum of A_s and A_s' (total reinforcement)
n = ratio of modulus of elasticity of steel to that of concrete

Reinforcement equally distributed around circumference

Assuming no tensile stresses in concrete, to obtain simplified formulas it is further assumed (a) that the reinforcement is located on the pipe's medial circumference, and (b) that the maximum permissible stress f_c is referred to point A and not to point A′ (Fig. 1).

Actually, (a) the longitudinal reinforcement is slightly outside the medial line which ensures a slightly increased margin of safety; and (b) taking into account the slenderness of the pipe wall, the maximum compression at point A′ at the top is somewhat higher than f_c, but the error is negligible.

In accordance with Fig. 1:

$$f_s' = nf_c \qquad 2r = D - t$$

$$x = \frac{nf_c}{nf_c + f_s}\, 2r \qquad \sin \alpha = \frac{r - x}{r}$$

The compressive stress z at a point y distance above the mentioned axis is:

$$z = f_c \frac{y}{x}$$

where: $y = r \sin (\phi + \alpha) - (r - x)$

The total concrete compressive force is then:

$$P_c = \int_0^{\pi - 2\alpha} ztrd\phi = trf_c \int_0^{\pi - 2\alpha} \frac{r \sin (\phi + \alpha) - (r - x)}{x} d\phi$$

$$= \frac{trf_c}{1 - \sin \alpha} [2 \cos \alpha - \sin \alpha (\pi - 2\alpha)] \qquad (1)$$

If a_s denotes the reinforcement per unit length of circumference, A_T

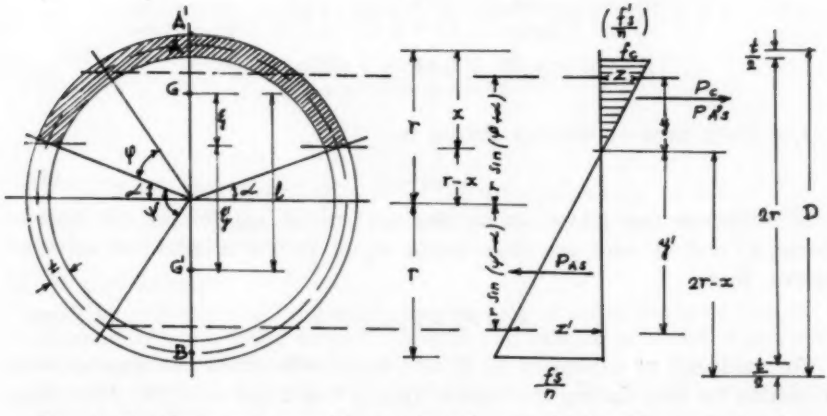


Fig. 1—Reinforcement equally distributed around circumference of pole

the total reinforcement, and A_s and A_s' the tensile and compressive reinforcement, respectively, then:

$$A_T = A_s + A_s' = 2\pi r a_s \quad (2)$$

The total compressive force on A_s' is:

$$P_{A_s'} = \int_0^{\pi - 2\alpha} a_s f_s' r \frac{r \sin(\phi + \alpha) - (r - x)}{x} d\phi$$

$$= \frac{A_T f_s'}{2\pi (1 - \sin\alpha)} [2\cos\alpha - \sin\alpha (\pi - 2\alpha)] \quad (3)$$

The tensile stress z' in reinforcement at a point y' distance below the neutral axis is:

$$z' = f_s \frac{y'}{2r - x}$$

where: $y' = r \sin(\psi - \alpha) + (r - x)$

The total tensile force on A_s is therefore

$$P_{As} = \frac{A_T f_s}{2\pi} \int_0^{\pi + 2\alpha} z' d\psi = \frac{A f_s}{2\pi} \int_0^{\pi + 2\alpha} \frac{r \sin(\psi - \alpha) + (r - x)}{2r - x} d\psi$$

$$= \frac{A_T}{2\pi (1 + \sin\alpha)} [2\cos\alpha + \sin\alpha (\pi + 2\alpha)] \quad (4)$$

The distance of application of forces ξ and ξ' are, respectively:

$$\xi = \frac{\int y dP_c}{P_c} = \frac{\int y^2 d\phi}{\int y d\phi} = \frac{\int_c^{\pi - 2\alpha} [r \sin(\phi + \alpha) - (r - x)]^2 d\phi}{\int_c^{\pi - 2\alpha} [r \sin(\phi + \alpha) - (r - x) d\phi}$$

$$= r \frac{\frac{1}{2}(\pi - 2\alpha) - \frac{3}{2}\sin 2\alpha + \sin^2\alpha (\pi - 2\alpha)}{2\cos\alpha - \sin(\pi - 2\alpha)} \quad (5)$$

$$\xi' = \frac{\int y' dP_{As}}{P_{As}} = \frac{\int y'^2 d\psi}{\int y' d\psi} = \frac{\int_c^{\pi + 2\alpha} [r \sin(\psi - \alpha) + (r - x)]^2 d\psi}{\int_c^{\pi + 2\alpha} [r \sin(\psi - \alpha) + (r - x)] d\psi}$$

$$= r \frac{\frac{1}{2}(\pi + 2\alpha) + \frac{3}{2}\sin 2\alpha + \sin^2\alpha (\pi + 2\alpha)}{2\cos\alpha + \sin\alpha (\pi + 2\alpha)} \quad (6)$$

The lever arm of interior forces is:

$$l = \xi + \xi' \quad (7)$$

If moments are taken about the centers of application of interior forces G and G' and are then made equal to the moment of exterior forces, then:

$$M = P_c l + P_{A_s'} l = P_{As} l \quad (8)$$

For each set of values of f_s, f_c, and n Eq. (8) gives the fundamental formulas for calculating the medial radius r and the total reinforcement A_T, as explained in the following example.

Example

$$f_s = 24{,}000 \text{ psi}; \qquad f_c = 1200 \text{ psi}; \qquad n = 10$$

$$x = \frac{nf_c}{nf_c + f_s} 2r = \frac{2}{3} r; \qquad \sin \alpha = \frac{r - x}{x} = \frac{1}{2}; \qquad \alpha = 30 \text{ deg} = 0.52 \text{ radians}$$

$$\pi - 2\alpha = 2.10; \qquad \pi + 2\alpha = 4.28; \qquad f_s' = nf_c = 12{,}000 \text{ psi}$$

$$\sin 2\alpha = 0.87; \qquad 2 \cos \alpha = 1.74$$

$$\frac{1}{1 - \sin \alpha} = 2; \qquad \frac{1}{1 + \sin \alpha} = \frac{2}{3}$$

and:

$$P_c = 2tr\,1200 \left[1.74 - \frac{1}{2} 2.10 \right] = 1660\, tr \qquad (1.1)$$

$$P_A{}'_s = 2A_r \frac{1200}{2\pi} \left[1.74 - \frac{1}{2} 2.10 \right] = 2640\, A_r \qquad (3.1)$$

$$P_{As} = \frac{2}{3} A_r \frac{24{,}000}{2\pi} \left[1.74 + \frac{1}{2} 4.28 \right] = 9900\, A_r \qquad (4.1)$$

$$\xi = r \frac{\frac{1}{2} 2.10 - \frac{3}{2} 0.87 + \frac{1}{4} 2.10}{1.74 - \frac{1}{2} 2.10} = \frac{0.27}{0.69} r = 0.39r \qquad (5.1)$$

$$\xi' = r \frac{\frac{1}{2} 4.28 + \frac{3}{2} 0.87 + \frac{1}{4} 4.28}{1.74 + \frac{1}{2} 4.28} = \frac{4.51}{3.88} r = 1.16r \qquad (6.1)$$

$$l = \xi + \xi' = 1.55r \qquad (7.1)$$

Therefore:

$$M = 1660\, tr \times 1.55\, r + 2640\, A_r \times 1.55\, r = 9900\, A_r \times 1.55\, r \qquad (8.1)$$

$$A_r = \frac{1}{4.38} tr = \frac{M}{15{,}200\, r} \qquad (9.1)$$

$$r = \frac{1}{59} \sqrt{\frac{M}{t}} \qquad (10.1)$$

Eq. (9.1) and (10.1) are sufficient for the determination of A and r.

Since $D = 2r + t$, the external diameter is easily obtained as shown in the following numerical example.

Numerical example

A corner pole made of reinforced concrete pipe of a net height of $h = 30$ ft is subjected to two traction forces T set at 90 deg, each equal to 400 lb and wind force acting along the diagonal equal to 100 lb (Fig. 2).

Find the required diameter and reinforcement at the base if the thickness of wall is $t = 2$ in.

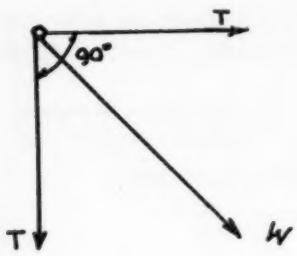


Fig. 2—Example problem

Solution

The total force is: $Q = T\sqrt{2} + W = 400\sqrt{2} + 100 = 666$ lb

and $M = 666 \times 30 \times 12 = 240{,}000$ in.-lb

According to Eq. (9.1) and (10.1)

$$r = \frac{1}{59}\sqrt{\frac{240{,}000}{2}} = 5.85 \text{ in.}; \qquad A = \frac{1}{4.38}\, 2 \times 5.85 = 2.67 \text{ sq in.}$$

$$D = 2 \times 5.85 + 2 = 13.7 \text{ in.}$$

Reinforcement concentrated at opposite points

Since in case of rupture or removal of cables the pull may occur on either side, the reinforcement should be equal at opposite points of the section (Fig. 3), i.e.:

$$A_s' = A_s = \tfrac{1}{2} A_r$$

The center of application of total force on the concrete remains G. The centers of application of forces on reinforcement are assumed to be A and B. Consequently, the fundamental equations will be obtained by equalling inner and outer moments, and by equalling the inner forces:

$$M = P_c\,(2r - x + \xi) + \frac{1}{2} A_r f_c'\, 2r \qquad \text{.....(11)}$$

and

$$P_c + \tfrac{1}{2} A_r f_c' = \tfrac{1}{2} A_r f_s \qquad \text{.....(12)}$$

If the figures of the previous example are adopted, then:

$$M = 1660\, tr\, (\tfrac{1}{3} + 0.39)\, r + \tfrac{1}{2} A_r\, 12{,}000 \times 2r$$

$$1660\, tr + \tfrac{1}{2} A_r\, 12{,}000 = \tfrac{1}{2} A_r\, 24{,}000$$

or

$$M = 2850\, tr^2 + 12{,}000\, A_r r$$

and

$$A_r = \frac{1}{3.62}\, tr = \frac{M}{22{,}000r} \qquad \text{.....(9.2)}$$

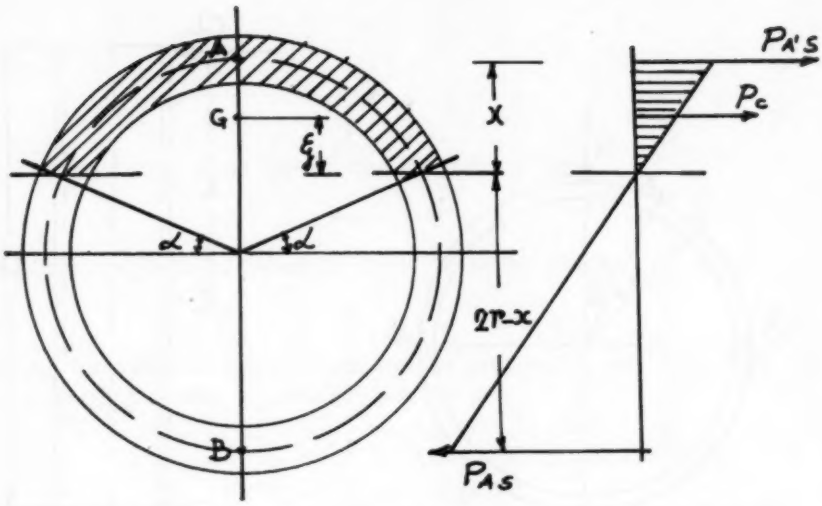


Fig. 3—Reinforcement concentrated at opposite sides of pole

$$r = \frac{1}{78.5}\sqrt{\frac{M}{t}} \qquad (10.2)$$

Eq. (9.2) and (10.2) give the dimensions and reinforcement required which, obviously, are much smaller than in the previous example.

It should be noted that (1) Some additional reinforcement should be added to withstand forces in other directions. (2) Wind and traction forces should be dealt with separately as the pole is normally subjected to wind only and traction occurs only with the rupture of cables.

Cosine distribution of reinforcement

It is known from the exact theory of three-dimensional structures* that in the case of a hollow vertical cylinder, fixed at its base and subjected to a horizontal force Q (see Fig. 4 and 5), the force at a section KL x distance below Q, and at an angle ϕ to the direction of Q, is

$$n_s = \frac{Qx}{\pi r^2}\cos\phi = \frac{M}{\pi r^2}\cos\phi$$

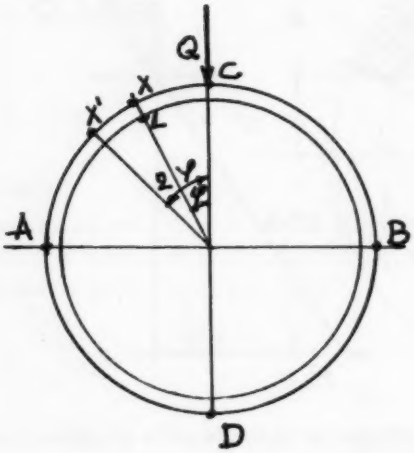
The total force on the half section ACB is

$$P = \int_{-\pi/2}^{+\pi/2} n_s r d\phi = \frac{2M}{\pi r}$$

Now, if the reinforcement is distributed so that there is equal stress at any section, i.e., f_s is constant, then

$$A_s f_s = P = \frac{2M}{\pi r}$$

and the reinforcement for the whole section is



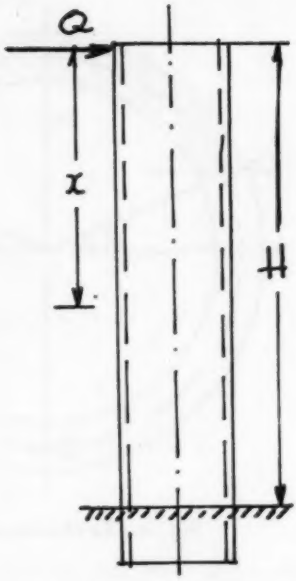


Fig. 4 (left)—Plan view of cylindrical pole. Fig. 5 (right)—Elevation

$$A_T = 2A_s = \frac{4M}{\pi r f_s} \qquad (13)$$

The amount of reinforcement in section KC is:

$$a_{s1} = \frac{M}{\pi r^2 f_s} \int_0^{\phi} r \cos\phi \, d\phi = \frac{M}{\pi r f_s} \sin\phi$$

and in section KK'

$$a_{s2} = \frac{M}{\pi r f_s} (\sin 2\phi - \sin\phi)$$

By this method the reinforcement is easily distributed along the circumference.

At point *D*:

$$\phi = -\pi; \qquad \cos\phi = -1$$

maximum compression is:

$$-n_{s\,max} = \frac{M}{\pi r^2} = t f_c + a_s f_s'$$

with

$$a_s = \frac{M}{\pi r f_s} \frac{\sin\phi}{r\phi} \Big|_{\phi \to 0} = \frac{M}{\pi r^2 f_s}$$

therefore:

$$\frac{M}{\pi r^2} = tf_c + \frac{M}{\pi r^2}\,\frac{f_s'}{f_s}$$

and:

$$r = \sqrt{\frac{M}{\pi t}\,\frac{f_s - f_s'}{f_s f_c}} \qquad (14)$$

According to the same theory, the shear force is

$$n_{r\phi} = \frac{Q}{\pi r}\sin\phi$$

If the shear is to be taken by concrete alone, then

$$V_{max} = \frac{Q}{\pi r t} \qquad (15)$$

Using the same permissible stresses as previously, i.e., $f_c = 1200$ psi, $f_s = 24{,}000$ psi, and $f_s' = 12{,}000$ psi, we get:

$$A_r = \frac{M}{18{,}840r} \qquad (13.1)$$

$$r = \frac{1}{87}\sqrt{\frac{M}{t}} \qquad (14.1)$$

This distribution of reinforcement enables the pole to withstand bending moments in the perpendicular direction, i.e., it is suited to withstand wind action or traction at an angle. The theoretical determination in the perpendicular direction involves, however, integration difficulties which, if solved by development in series, would present formulas too cumbersome for use; this part, therefore, has been omitted as it would seem more reliably established by tests.

PRESTRESSED REINFORCEMENT

Only the case of prestressed reinforcement uniformly distributed along the circumference is considered, all other cases can be similarly computed. Accordingly, the reader is referred to p. 1049 and to Fig. 1.

At first, it is assumed that the concrete alone has to withstand the bending moment; therefore, it is subjected to equal compression and tension at both extremities (Fig. 6). Accordingly, referring to Fig. 1: $x = r$ and $\alpha = 0$.

Introducing these values in Eq. (1), (5), (6), and (7):

$$P_c = |\,-P_c\,| = 2trf_c \qquad (1p)$$

$$\xi = \xi' = \frac{\pi r}{4} \qquad (5p)$$

$$l = \xi + \xi' = \frac{\pi r}{2} \qquad (7p)$$

According to Fig. 6:

$$M = P_c l = 2trf_c\frac{\pi r}{2} = \pi r^2 f_c t \qquad (8p)$$

*See Girkman, *Flaechentragwerke*, 2nd Edition pp. 324-332.

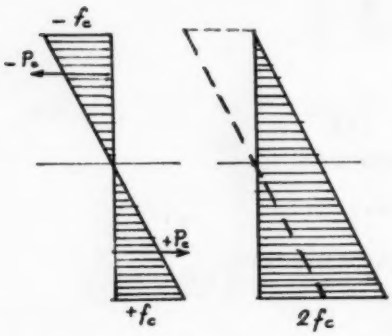


Fig. 6—Case for prestressed reinforcement

$$r = \sqrt{\frac{1}{\pi f_c}\,\frac{M}{t}} \qquad \text{(10p)}$$

Next, the uniformly distributed reinforcement is prestressed in a manner as to neutralize the maximum tensile stress in the concrete. Consequently, if a_s is as previously, the reinforcement per unit length of the circumference, then:

$$f_s a_s = f_c t$$

and since

$$A_T = 2\pi r a_s \qquad \text{(see p. 1050, Eq. 2)}$$

then

$$f_s A_T = 2\pi r\, f_c t$$

and

$$A_T = 2\pi r t\,\frac{f_c}{f_s} \qquad \text{(9p)}$$

Now the concrete has been compressed by prestressing to the limit f_c and has then been subjected to a bending moment which has caused additional compression of f_c, i.e., the total stress in the extreme fiber is 2 f_c (see Fig. 6).

Similarly, the reinforcement is strained to the limit 2 f_s.*

According to the ACI Code for flexure, the values of f_c and f_s should be taken as approximately half of the ultimate strength. In prestressing, however, the permissible stresses can be taken much nearer to the ultimate strength since there is no fear of cracks due to tensile stresses in concrete. In this case it is proposed, therefore, to fix the permissible stresses both for concrete and steel as 2/3 of ultimate strength stresses. The values of f_c and f_s to be introduced in Eq. (15p), (16p), and (17p) will therefore be:

*Utility poles are subjected to cable traction or wind pressure from both sides, whereas ordinary beams under vertical loads are subjected to forces in one direction only. Therefore, ordinary beams are prestressed on the tension side only whereas poles are prestressed symmetrically on both sides with the resulting doubled stress in concrete and double amount of prestressing steel.

$f_c = \frac{1}{2} \times \frac{2}{3} \times$ ultimate concrete stress $= \frac{1}{3}$ ultimate concrete stress

$f_s = \frac{1}{2} \times \frac{2}{3} \times$ ultimate steel tensile stress $= \frac{1}{3}$ ultimate steel tensile stress

Example

The ultimate stresses for concrete and steel are respectively, 6000 and 120,000 psi; $f_c = \frac{1}{3} \times 6000 = 2000$ psi; $f_s = \frac{1}{3} \times 120{,}000 = 40{,}000$ psi.

Accordingly

$$A_r = \frac{1}{3.18}\, tr = \frac{M}{20{,}000r} \qquad (9p.1)$$

and

$$r = \frac{1}{79.3}\sqrt{\frac{M}{t}} \qquad (10p.1)$$

SUMMARY

Problems facing the designer of utility poles made of reinforced concrete pipes have been reviewed. Formulas have been established for cylindrical and slightly conical pipe with circular sections serving as poles. It has been shown that:

1. The most economical solution for poles with main moments in one direction is to concentrate reinforcement at two opposite points.
2. The cosine distribution of reinforcement offers less reinforcement and a smaller diameter than reinforcement uniformly distributed.
3. Prestressing does not offer as much material advantage over simple reinforcement as in cases of structures subjected to loads from one direction.

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Title No. 56-53

Design of Unsymmetrical Reinforced Concrete Sections

By A. SIEV

Reasons for loading these beams in the plane of the major principal axis are discussed. A method for determining this axis for unsymmetrically reinforced concrete sections in cracked-elastic and cracked-plastic stages is presented. Design equations are derived, followed by an example problem.

■ AN UNSYMMETRICAL BEAM USUALLY has a simpler form (Fig. 1). In precast reinforced concrete beams, the unsymmetrical section has an important advantage from the production point of view, since it permits casting from the flat side and immediate reuse of the forms (Fig. 2).

However, unless the slope of the neutral axis is correct, the flange may actually cause higher stresses compared with a rectangular cross section, instead of the required lower stresses.

A comparison of different flanges and their effect (Fig. 3) shows that the addition of an unsymmetrical flange (Fig. 3b) results in higher stresses, while the symmetrical flange (Fig. 3c) reduces them.

The steep slope of the neutral axis (Fig. 3b) and the tensile stresses in the right hand half of the flange may be explained by the verticality of the external moment; the resultant of tension T at the bottom of the web (with point of application inside the web) calls for a stress distribution in the flange, the resultant of which will be on a vertical line through T.

In these circumstances, it is impossible to obtain a horizontal neutral axis even in the plastic stage. As deflections are normal to the neutral axis it follows from Fig. 3b that horizontal deflections are larger than the vertical ones, resulting in additional torsional moments. In slender beams the horizontal deflections are thus increased nonlinearly with the load.

A small rotation, so as to have the principal vertical axis coincide with the moment plane (with force passing through center of twist),

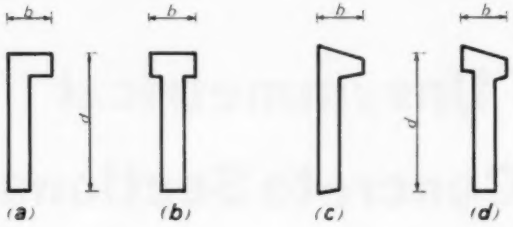

Fig. 1 — Examples of symmetrical and unsymmetrical sections

improves the stress distribution (Fig. 4) and also eliminates horizontal deflections.

The stresses in unsymmetrical sections in plane bending (Fig. 4) are nearly the same as in a similar symmetrical section (Fig. 3c); this fact can be put to advantage by using symmetrical dimensioning for unsymmetrical sections. Thus in reinforced concrete sections the main dimensions may be computed from tables for T-sections with the required shape and slope subsequently adjusted.

Notation

A = cross section of compressed area
b = width of beam
C = resultant of compressive stresses
d = effective depth of beam
e = eccentricity of C with respect to y-axis
f_c = stress in concrete
f_s = stress in steel
I_{xx} = moment of inertia about the x-axis
I_{yy} = moment of inertia about the y-axis
I_{xy} = product of inertia
j = ratio of distance (jd) between resultants of compressive and tensile stresses to effective depth
k = ratio of distance (kd) between extreme fiber on y-axis and neutral axis to effective depth
m = distance of C from neutral axis
n = E_s/E_c
S_x = first moment of area about the x-axis
S_y = first moment of area about the y-axis
T = resultant of tensile stresses in reinforcing bar
α = angle or rotation of the beam for improved design
β = angle at T between $\overline{TO}$ and $\overline{TC}$

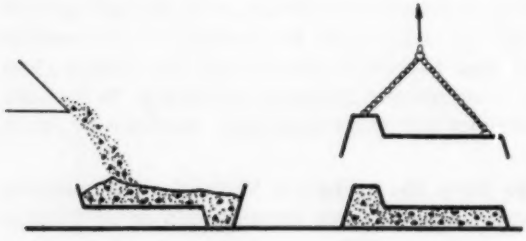

Fig. 2 — Advantage in production of unsymmetrical beams is the immediate reuse of forms

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DETERMINATION OF PRINCIPAL AXES IN UNSYMMETRICAL SECTIONS

All known methods for determining the conjugate axis in reinforced concrete sections are based on trial and error approximations.

The suggested method converges rapidly and gives sufficiently accurate results for the first approximation.

Dimensions are determined as for a symmetrical T-section.

Cracked-elastic stage

In the section of Fig. 5, let the y-axis pass through the center of the reinforcing bar, parallel to the plane of the external moment.

Assume that the neutral axis coincides with the x-axis. Considering the area of compression only (above the x-axis), the resultant, C, of the compressive stresses is

$$C = \frac{f_{max}}{kd} \int\int y \, dxdy = \frac{f_{max}}{kd} S, \quad \ldots\ldots (1)$$

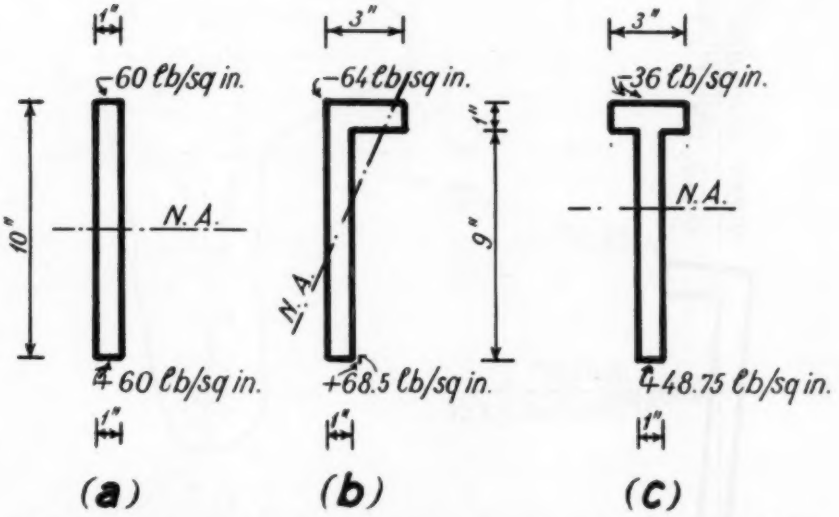


Fig. 3—Stress diagrams for flanged sections (homogeneous material) under the same moment (1000 in.-lb)

The moment of C about the x-axis is equal to the sum of its components:

$$mC = \frac{f_{max}}{kd} \iint y^2 dx dy = \frac{f_{max}}{kd} I_{xx} \quad \text{.....(2)}$$

and that about the y-axis:

$$eC = \frac{f_{max}}{kd} \iint x\, y\, dx dy = \frac{f_{max}}{kd} I_{xy} \quad \text{.....(3)}$$

In the above formulas the integral refers to the area above the x-axis.

If $I_{xy} = 0$, then $e = 0$ and C falls on the y-axis, so that the vectors of internal and external moments are in equilibrium.

If $I_{xy} \neq 0$, the section should be rotated about the center of the reinforcing bar through an angle α, such that $I_{x'y'} = 0$. (The compressive area, with respect to the x-y-system is slightly different from that of the x'-y'-system, but the difference is negligible.)

Rotation of the section is equivalent to a rotation of the axes through an angle α and a translation of the origin from 0 to 0′.

$$\overline{00'} = \alpha\, d\,(1 - k)$$

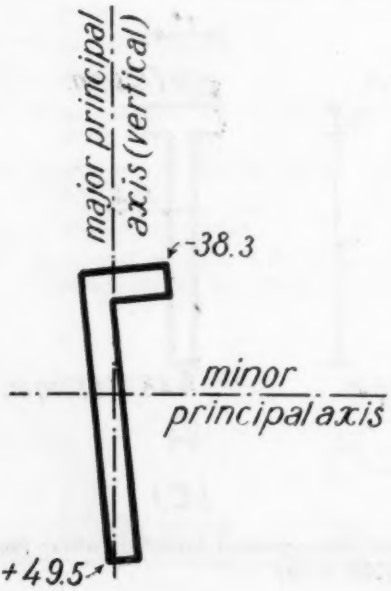


Fig. 4—Stresses in section in Fig. 3b when rotated for plane bending

For a small angle,

$$\sin\alpha = \alpha \qquad \cos\alpha = 1$$

$$x' = x\cos\alpha - y\sin\alpha - \alpha d\ (1-k) = x - \alpha y\ - \alpha d\ (1-k)$$

$$y' = x\sin\alpha + y\cos\alpha = \alpha x + y$$

$$I_{x'y'} = \iint x'y'\ dxdy = \alpha \iint x^2\,dxdy\ + \iint x\,y\,dxdy - \alpha^2 \iint x\,y\,dxdy - \alpha \iint y^2\,dxdy$$

$$- \alpha^2 d(1-k) \iint x\,dxdy - \alpha\, d(1-k) \iint y\,dxdy = \alpha\, I_{yy} + I_{xy} - \alpha^2 I_{xy} -$$

$$\alpha I_{xx} - \alpha^2 d(1-k)\ S_x - \alpha d(1-k)\ S_x = 0$$

Neglecting small terms of the second order we obtain

$$I_{xy} - \alpha\,[I_{xx} + d(1-k)\ S_x - I_{yy}] = 0$$

$$\alpha = \frac{I_{xy}}{I_{xx} + d(1-k)\ S_x - I_{yy}} \qquad \ldots\ldots(4)$$

Dividing Eq. (2) by Eq. (1)

$$m = \frac{I_{xx}}{S_x}$$

$$I_{xx} = mS_x \qquad \ldots\ldots(5)$$

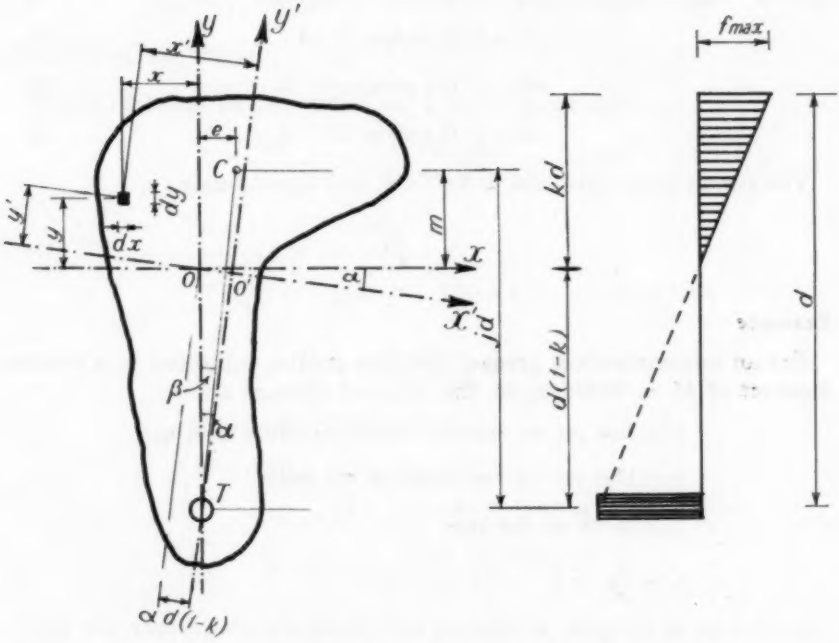


Fig. 5—Unsymmetrical section in cracked-elastic stage

Introducing I_{xx} from Eq. (5) into Eq. (4)

$$\alpha = \frac{I_{xy}}{[d(1-k)+m]\,S_x - I_{xy}} = \frac{I_{xy}}{S_x \cdot j \cdot d - I_{xy}} \quad \ldots\ldots (6)$$

But by Eq. (1) and (3)

$$e = \frac{I_{xy}}{S_x} = \beta j d \quad \ldots\ldots (7)$$

For slender beams the second term of the denominator is small compared with the first, so that α is only slightly larger than β.

It can be seen that the section should be rotated so that C will fall near the y-axis.

The procedure is somewhat more complicated in such cases as sloping roof purlins where a slight alteration in the shape of the section is necessary to fit the upper slope.

Cracked-plastic stage

Stresses are assumed to be as shown in Fig. 6. By following the same procedure, equations similar to those of Eq. (1), (2), and (3) are obtained.

$$C = f_c' \iint dx dy = f_c' \cdot A \quad \ldots\ldots (8)$$

$$mC = f_c' \iint y\, dx dy = f_c' \cdot S_x \quad \ldots\ldots (9)$$

$$eC = f_c' \iint x\, dx dy = f_c' \cdot S_y \quad \ldots\ldots (10)$$

The condition in this case is $Sy' = 0$, and analogously,

$$\alpha = \frac{S_y}{A_{f-s}} \quad \ldots\ldots (11)$$

Example

For an unsymmetrical precast concrete purlin, subjected to a vertical moment of $M = 70{,}000$ in.-lb, the allowed stresses are:

$f_c = 1100$ psi for concrete vertically above steel bar

$f_c < 1300$ psi for far corner of the beam

$f_s = 25{,}000$ psi for steel

$$n = \frac{E_s}{E_c} = 7$$

Slope of upper surface is 10 deg. Width of compression flange is 4½ in.

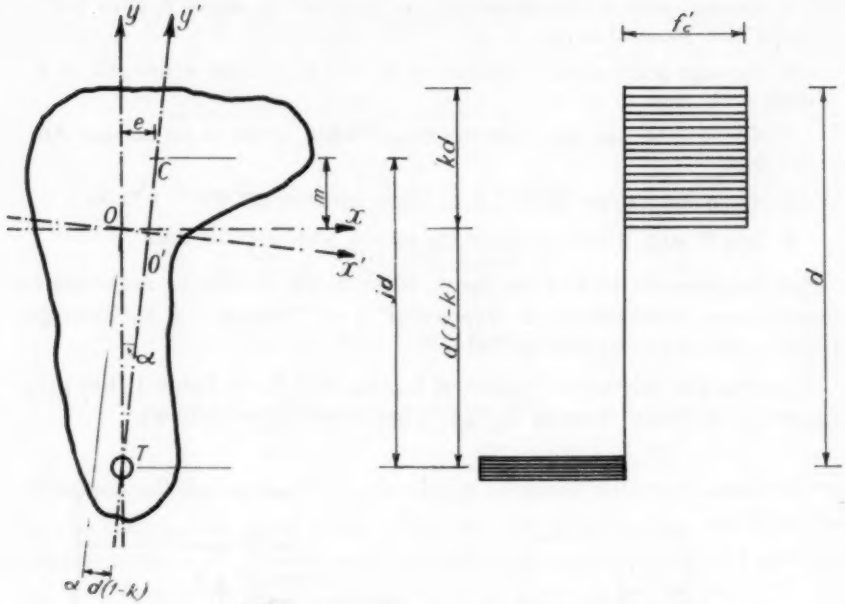


Fig. 6—Unsymmetrical section in cracked-plastic stage

Cracked-elastic stage

Depth of beam as calculated for a rectangular section.

$$k = \frac{nf_c}{f_s + nf_c} = \frac{7 \times 1100}{25{,}000 + 7 \times 1100} = 0.236$$

$$j = 1 - \frac{k}{3} = 0.921$$

$$K = \frac{1}{2} \cdot f_s \cdot kj = \frac{1}{2} \times 1100 \times 0.236 \times 0.921 = 119.5$$

$$d = \sqrt{\frac{M}{bK}} = \frac{70{,}000}{4.5 \times 119.5} = 11.4 \text{ in.}$$

$$kd = 0.236 \times 11.4 = 2.69 \text{ in.}$$

$$jd = 0.921 \times 11.4 = 10.5 \text{ in.}$$

$$(1 - k)d = 11.4 - 2.69 = 8.71 \text{ in.}$$

$$C = T = \frac{70{,}000}{0.921 \times 11.4} = 6660 \text{ lb}$$

With the above data available, the procedure (Fig. 7) is as follows:

1. Draw a vertical line through T (center of reinforcing bar).

2. Through point 0, at a distance $d(1 - k) = 8.71$ in. above T, draw horizontal line (neutral axis).

3. Through point A, at a distance of $d = 11.4$ in. draw a line $\overline{AB}$ at a slope of 10 deg.

4. $\overline{AB}$ must be less than half the flange width which is 4.5 in., say $\overline{AB} = 1.5$ in.

5. Assuming the web to be 1.5 in. thick, measure off TD = 0.75 in.

6. Join D with B and complete the section with parallel lines.

The compressive area of the beam, refer to Fig. 8, will be regarded for convenience as consisting of "Trapezoid" 1 — "Triangle" 2 + "Triangle" 3. The calculations appear in Table 1.

By using the calculated values of I_{xx}, I_{xy}, and S_x in Table 1, the properties for the beam section in Fig. 8 are obtained as follows:

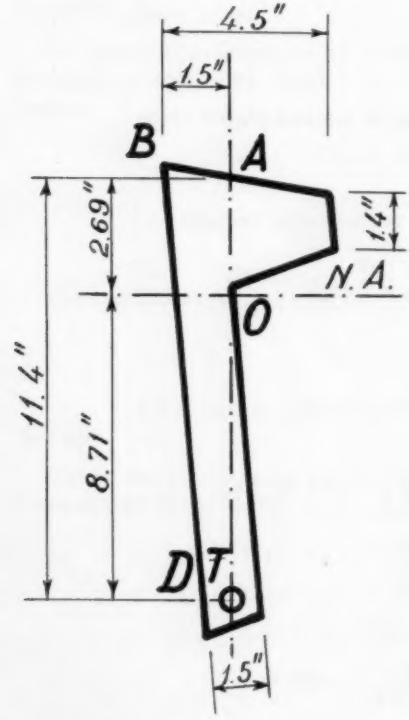


Fig. 7—Construction procedure

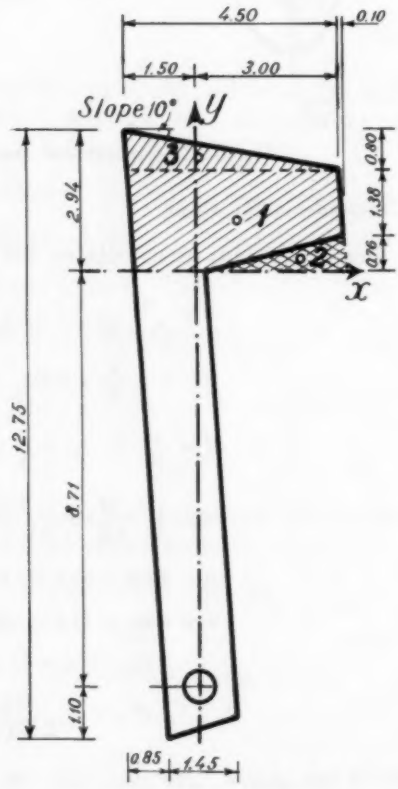


Fig. 8—First approximation

$$e = \frac{I_{xy}}{S_x} = \frac{7.60}{14.24} = 0.533 \text{ in.}$$

$$m = \frac{I_{xx}}{S_x} = \frac{24.85}{14.24} = 1.745 \text{ in.}$$

$$jd = 8.71 + m = 8.71 + 1.75 = 10.46 \text{ in.}$$

$$C = \frac{f_c S_x}{kd} = \frac{1100 \times 14.24}{2.69} = 5830 \text{ lb}$$

$$M = jdC = 10.46 \times 5830 = 61{,}000 \text{ in.-lb}$$

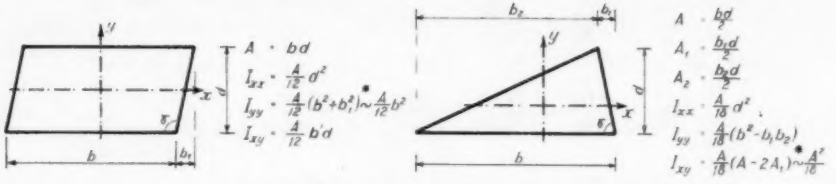
$$d = \frac{dI_{xy}}{jdS_x - I_{xy}} = \frac{11.4 \times 7.60}{10.5 \times 14.24 - 19.48} = 0.665 \text{ in.}$$

Rotation of the section in the direction obtained will increase its bending resistance, but most likely still not enough to give the required resistance moment. Hence depth should be increased by say 2.5 percent.

TABLE 1—CALCULATIONS FOR PROPERTIES OF UNSYMMETRICAL BEAM—CRACKED-ELASTIC STAGE*

		Dimension	(+) Area No. 1	(−) Area No. 2	(+) Area No. 3	Total
b		in.	4.45	2.98	4.45	—
d		in.	2.14	0.76	0.80	—
A		sq. in.	9.52	−1.03	+1.78	10.27
x		in.	0.86	2.14	0.04	
y		in.	1.07	0.24	2.41	
$S_y = Ax$		in.³	10.20	−0.25	4.29	14.24
$S_x = Ay$		in.³	8.18	−2.20	0.07	6.05
I_{xx}	Ay^2	in.⁴	+ 3.63† +10.90	−0.03 −0.06	+ 0.06 +10.35	
	Total		+14.53	−0.09	10.41	24.85
I_{yy}	Ax^2	in.⁴	15.70 + 7.04	−0.51 −4.71	+ 1.96 + 0.00	
	Total		22.74	−5.22	+ 1.96	19.48
I_{xy}	Axy	in.⁴	− 0.31 + 8.85	− 0.06 −0.53	− 0.18 0.17	
	Total		+ 8.54	−0.59	− 0.35	+ 7.60

*First approximation, Fig. 8.
†Moments of inertia about the section centroid (upper figures, I_{xx}, I_{yy}, and I_{xy}) are calculated by the formulas given in Fig. 9.



* In this specific example, since θ is nearly a right angle.

Fig. 9—Properties of sections

To check the accuracy of the above results a second approximation is made, the calculations of which appear in Table 2.

Second approximation (Fig. 10):

$$d = 1.025 \times 11.4 = 11.7 \text{ in.}$$

$$kd = 0.236 \times 11.7 = 2.76 \text{ in.}$$

$$e = \frac{I_{xy}}{S_x} = -\frac{1.31}{15.85} = -0.083 \text{ in.}$$

TABLE 2—CALCULATIONS FOR PROPERTIES OF UNSYMMETRICAL BEAM—CRACKED-ELASTIC STAGE*

		Dimension	(+) Area No. 1	(−) Area No. 2	(+) Area No. 3	Total
b		in.	4.40	2.91	4.40	
d		in.	2.32	0.95	0.80	
A		sq. in.	+10.20	−1.38	+ 1.76	10.58
x		in.	+ 0.25	+1.59	− 0.65	
y		in.	+ 1.15	+0.30	+ 2.58	
$S_y = Ax$		in.³	+ 2.55	−2.20	− 1.15	− 0.80
$S_x = Ay$		in.³	+11.72	−0.42	+ 4.55	+15.85
I_{xx}	Ay^2	in.⁴	+ 4.58 13.50	−0.07 −0.12	+ 0.07 +11.70	
	Total		+18.08	−0.19	+11.7	+29.66
I_{yy}	Ax^2	in.⁴	16.40 + 0.64	−0.65 −3.49	+ 1.89 + 0.75	
	Total		17.04	−4.14	+ 2.64	+15.54
I_{xy}	Axy	in.⁴	− 0.35 + 2.93	−0.11 −0.65	− 0.17 − 2.95	
	Total		2.58	−0.76	− 3.13	− 1.31

*Second approximation, Fig. 10.

For practical purposes the resultant compressive stress may be assumed on the y-axis, i.e., bending is in the principal bending plane.

$$m = \frac{I_{ss}}{S_s} = \frac{29.66}{15.85} = 1.875 \text{ in.}$$

$$jd = 8.71 + m = 10.585 \text{ in.}$$

$$C = \frac{f_c S_s}{kd} = \frac{1100 \times 15.85}{2.76} = 6320 \text{ lb}$$

$$M = jdC = 10.585 \times 6320 = 68{,}000 \text{ in.-lb}$$

$$f_{c_B} = \frac{1100 \times 3.12}{2.76} = 1240 \text{ psi}$$

$$A_s = \frac{6320}{25{,}000} = 0.252 \text{ sq in.}$$

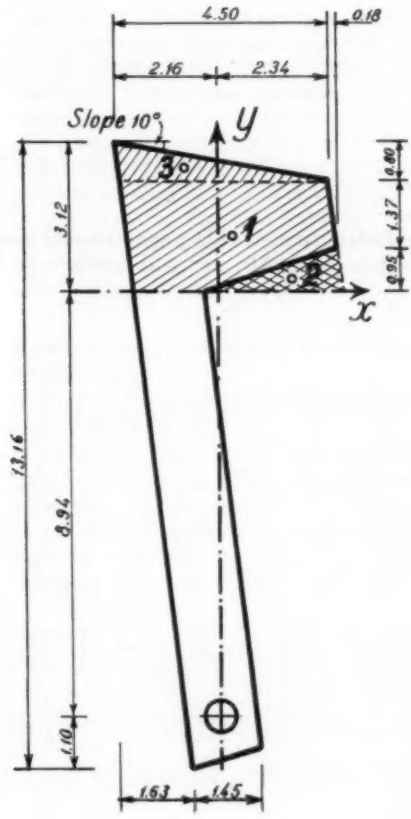


Fig. 10—Second approximation

It is seen that in practice the approximation obtained from Table 1 is satisfactory for a semigraphical solution and that the second table is unnecessary except as a check.

Cracked-plastic stage

Dividing Eq. (10) by Eq. (8) we obtain e; introducing values from Table 2 we have

$$e = \frac{S_y}{A} = -\frac{0.80}{10.58} = -0.075 \text{ in.}$$

This means that this slope is suitable for the plastic stage as well. Numerical calculation shows that this remains true even when the neutral axis is shifted upward, or for an uncracked section under low load.

The same method may also be used for more than one reinforcing bar by reference to the centroid of the reinforcement as point T, provided all bars are at equal distances from the neutral axis.

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American Concrete Institute, P. O. Box 4754, Redford Station, Detroit 19, Mich.

Discussion of this paper should reach ACI headquarters in triplicate by July 1, 1960, for publication in Part 2, December 1960 JOURNAL.

CURRENT REVIEWS

of Significant Contributions in Foreign and Domestic Publications

Bridges

Survey of prestressed concrete bridges

P. E. Ellen, *N.Z. Concrete Construction* (Wellington), V. 3, No. 7, Aug. 1959, pp. 98-103

A survey was made during 1958 of prestressed concrete bridges having spans of 50 ft or more in New Zealand. The results are tabulated and give type of design, general cost, and location.

Design and construction of prestressed concrete bridge over Drava River at Ptuj (in Slovene)

J. Vogrinec, J. Stanic, B. Pipan, B. Hvasta, F. Runovc, P. Oman, F. Krajncic, F. Kerec, D. Jejcic, F. Cacovic, and S. Turk, *Gradbeni Vestnik* (Ljubljana), V. 9, No. 58-59, 1957-1958, pp. 1-31.

Reviewed by J. J. Polivka

Bidding for this bridge, one of the largest concrete bridges in Slovenia, was made on three alternative designs (reinforced concrete, prestressed concrete, and steel). The most favorable and economical alternative bid that was submitted was designed in prestressed concrete. The total length of the bridge is 221 m (725 ft) and has spans between abutments and piers of 2, 14.5, 54.5, 79, 54.5, 14.5, and 2 m. The total width is 13.2 m (44 ft) and consists of a 10 m-roadway and two sidewalks of 1.6 m each. Prestressed concrete cantilevers (box type) were built by movable forms. Prefabricated beams were made on the abutments and piers and then mounted by means of a cableway. Prestressing cables consisted of 18 wires, each having a 5-mm diameter. Of special interest is the method of prestressing and the test results.

Railroad and highway bridge at Abidjan, Ivory Coast (Le pont rail-route d'Abidjan)

J. Francois, *Annales*, Institut Technique du Bâtiment et des Travaux Publics (Paris), No. 138, June 1959, pp. 545-574

Reviewed by Henri Perrin

Describes the erection problems of this outstanding prestressed concrete bridge in Africa. Many sketches illustrate the construction procedures. Abutments and piers are supported by caissons. The superstructure consists of two huge prestressed concrete boxes; inside are the two railroad lines, on the top a four lane highway and two sidewalks. They were prefabricated in a near-by plant. The prestressing system is the same as the one used for the Voulte Viaduct [see Current Reviews, ACI Journal, V. 30, No. 10, Apr. 1959 (*Proceedings* V. 55) p. 1150].

Composite prestressed concrete bridge slabs

R. Park, *Proceedings*, Second National Prestressed Concrete Conference, Wellington, New Zealand, 1958, pp. 46-58

Reports the results of experimental work on two types of composite slabs. Attention was focused almost entirely upon varying the structural properties without varying the load position. Working load and ultimate load char-

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For those members who cut apart this section for pasting on cards for card indexes, a limited number of complimentary reprints of the "Current Reviews" section are available from ACI headquarters on request.

acteristics of these slabs were investigated, with particular emphasis on (1) the accuracy of the "distribution coefficient" method, due originally to Guyon and Massonnet for bending moments in the elastic range, and (2) the application of ultimate load theory to grouted and ungrouted post-tensioned concrete slabs.

Strength of simply supported slab bridges subjected to concentrated loads

P. B. Morice and G. C. Reynolds, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement and Concrete Association (London), 1958, pp. 557-575

Authors' Summary

A method is given for the limit analysis of skew bridge slabs, with or without edge beams. The results for the particular cases of right slabs are included. An attempt has also been made to suggest the required proportions of longitudinal and transverse reinforcement, or prestress, in right slabs to obtain a factor of safety for the whole structure which is consistent with the factor of safety of an element.

A number of tests have been carried out on both right and skew small-scale slabs in reinforced concrete. One right prestressed concrete slab has also been tested. The results are in reasonable agreement with those predicted by the analysis.

Tancarville suspension bridge

The Engineer (London), V. 208, No. 5403, Aug. 14, 1959, pp. 82-86

Tancarville — Europe's largest suspension bridge

Engineering (London), V. 188, No. 4871, Aug. 28, 1959, pp. 92-93

Reviewed by Aron L. Mirsky

This bridge, over the Lower Seine at Tancarville constitutes a notable first for concrete. For the first time, the towers, 390 ft high, are constructed of reinforced concrete. The composite deck, of steel sheet and concrete, which also acts on the top chord of the stiffening truss, is also an innovation in suspension bridge design. Of lesser novelty, but of strategic importance, are the massive concrete anchorages, particularly the one on the south bank.*

*These anchorages were described in more detail in *Engineering News-Record*, V. 162, No. 19, May 14, 1959, pp. 41-42, 44, 46.

Construction

How to design and construct cast concrete solar screens

Building Construction Illustrated, V. 29, No. 1, Jan. 1960, pp. 38-40

Illustrates and describes briefly some precast concrete screening. Design factors are considered briefly as are methods of attaching the screens to the structure.

Largest industrial building in Slovenia (Yugoslavia) on the Adriatic Sea (in Slovene)

F. Pecar, F. Maleiner, M. Gregoric, D. Smrekar, J. Zirovnik, and J. Kramaric, *Gradbeni Vestnik* (Ljubljana), V. 9, No. 55-57, 1957-1958, pp. 105-131

Reviewed by J. J. Polivka

A series of articles describes the motor plant "Tomos" in the Koper harbor. Main manufacturing building, covering 336,000 sq ft (480 x 700 ft) is a typical shell structure consisting of semicircular shells spanning 10 m, with vertical daylight walls resting on columns 20 m on center and supporting stiffening beams of the shells.

Rincon offshore island and open causeway

John A. Blume and James M. Keith, *Proceedings*, ASCE, V. 85, No. WW 3, Sept. 1959, pp. 61-92

Author's Summary

Presents the design problems and the construction techniques involved in creating a man-made island of sand, rock, and precast concrete armor in the Pacific Ocean offshore from California. This oil production island with the open causeway which connects it to the shoreline constitutes one of the most unique marine installations in the

world. The design included many alternate economic studies, model tests in a wave laboratory, and storm damage and wave runup studies with alternate armor types, materials, densities and slopes.

Industrialization, practice and specifications (Industrialisation, habitudes et reglements)

BALENCY-BEARN, *Annales*, Institut Technique du Bâtiment et des Travaux Publics (Paris), No. 135-136, Mar.-Apr. 1959, pp. 353-390
Reviewed by HENRI PERRIN

France is one of the western countries where mass production in housing has been the most industrialized. Although the total amount of apartments built during recent years is still far behind a conservative schedule, many efforts have been made to produce large prefabricated concrete elements and even complete concrete buildings on a mechanized basis. The various problems encountered by such undertakings are exposed in detail and illustrated.

Breakwater at Crescent City, California

JOHN E. DEIGNAN, *Proceedings*, ASCE, V. 85, No. WW 3, Sept. 1959, pp. 167-181
AUTHOR'S SUMMARY

The outer breakwater at Crescent City, completed in 1957, used tetrapods as the armor stone for the last section. Design of the breakwater and placement and construction of tetrapods provided engineering and construction problems of an unusual nature since this was the first use of tetrapods in the United States. The storm of April, 1958, approached design standards; only minor settling of tetrapods was noted.

Low-cost home shelter from nuclear blasts

HERBERT A. SAWYER, JR., *Civil Engineering*, V. 29, No. 12, Dec. 1959, pp. 54-57

Describes a shelter to provide protection from fire, blast, and fallout radiation for a family for about $450 to $650. Built adjacent to the house with a tunnel entrance from the basement, the shelter will accommodate six.

Built of concrete block with a reinforced concrete roof, the shelter provides blast protection from a 20-megaton weapon for a 40-mile radius.

Construction details and a bill of materials are included.

Germany likes concrete ties

GERHARD SCHRAMM, *Railway Age*, V. 146, No. 25, June 22, 1959, pp. 43, 46
Reviewed by ARON L. MIRSKY

Brief summary of history of concrete ties, development and improvement of prestressed ties, and the current practices of the German Federal Railroad.

RRs plan concrete-tie tests

Railway Age, V. 147, No. 19, Nov. 9, 1959, pp. 20-21
Reviewed by ARON L. MIRSKY

Based on extensive use of concrete ties in Germany (see review above), the properties of prestressed concrete and the advantages of such ties when used with continuous welded rail, several railroads, a concrete tie manufacturer, and the Association of American Railroads are planning test installations using a tie design developed from extensive preliminary tests.

Research and development of shock-controlled foundation for a heavy-gun laboratory testing-hammer

JAMES H. A. CROCKETT and DENIS B. O'NEILL, *Proceedings*, Institution of Civil Engineers (London), V. 13 (Session 1958-59), June 1959, pp. 133-160
Reviewed by ARON L. MIRSKY

Hammer used by British Ministry of Supply in developing heavy artillery has a sliding tup, with a variable weight of up to 10 tons, powered by compressed air acting on the piston of a 120-ton cylinder. The main problems involved in the design included highly-sensitive interferometers to be installed in an adjacent laboratory, shear in the hold-down bolts due to the relatively large elastic extension of the machine foundation girders under shock loading compared to the elastic extension of the concrete block, grip-stress (bond) fatigue, and concrete fa-

tigue. The solution included three-dimensional prestressing using both Freyssinet and Lee-McCall elements, very high quality grouted concrete, and large rubber springs. Test results indicate attainment of goal: ground vibrations are reduced to a "just perceptible" limit at about 120 ft instead of perhaps 2 miles, an insulation value of better than 99 percent. Theory, research, development, and construction are covered in detail.

Philips Pavilion at the 1958 Brussels World Fair

Philips Technical Review (Eindhoven, Netherlands), V. 20, No. 1, Sept. 1958

An extremely interesting and complete account of the pavilion built at the Brussels World Fair by N. V. Philips' Gloeilampenfabrieken. The four articles cover the architect's conception, the design theories and calculation, the model tests, and the actual construction of the building.

Architectural design of Le Corbusier and Xenakis

Y. Xenakis, pp. 2-8

A brief explanation is given of the visual, acoustical, and architectural considerations that led to the design of the pavilion as hyperbolic paraboloids. The evolution of the first design, which included conoids, is illustrated by a series of sketches, and a description is given of the method, half experimental and half geometrical, by which the surfaces of the first design were converted completely into hyperbolic paraboloids (second design).

Hyperbolic-paraboloidal shell and its mechanical properties

C. G. J. Vreedenburgh, pp. 9-17

After a recapitulation of the principal geometrical properties of the hyperbolic paraboloid (hypar), the author gives a synopsis of the membrane theory of the hypar shell. The differential equations for the state of stress can be solved simply in the case of a uniaxial uniform load parallel to the axis of the shell. The shell can then be considered as a structure of equal strength. The author also provides formulas for some more complex loads which may occur in practice, and describes a simple graphical method for determining the principal shell forces and the prestressing forces needed if tensile stresses are to be avoided in the concrete. Finally, attention is devoted to the edge disturbances which appear when the boundary conditions are such as to locally preclude a purely membrane state of stress, and to the stability of the hypar shell against buckling and second-order buckling.

Model tests for proving the construction of the pavilion

A. L. Bouma and F. K. Ligtenberg, pp. 17-27

A 1:25 scale model was made of the pavilion. The model was built of plaster of Paris on a framework of wiregauze, with steel tubes as the ribs. The states of stress produced in the model under different loads(deadweight, wind, etc.) were investigated with a large number of strain gages and displacement gages. The conclusion was that a structure of 5 cm thick concrete with 40 cm thick ribs would be sufficiently strong. In a second model, scale 1:10, two of the shell surfaces (formed as hyperbolic paraboloids) were built up from several hundred appropriately shaped plywood slabs. These shell surfaces were prestressed, and the results observed demonstrated the feasibility of the proposed system of construction, using precast concrete slabs and prestressing wires anchored in the ribs.

Construction of the pavilion in prestressed concrete

H. C. Duyster, pp. 27-36

The contractor built up the 5 cm thick walls from slabs about 1 sq m in size which were precast in sand molds and, after assembly on scaffolding, were pulled tightly together by steel wires. This construction was also mechanically advantageous, since with suitable prestressing of shells and edge members, a membrane state of stress could be approached. The precasting and as-

sembly of the slabs was greatly simplified by the fact that the walls were ruled surfaces (hyperbolic paraboloids). The prestressing wires, applied to both surfaces of the shells, followed mainly the ruling lines. They were tensioned by the strabed system. In addition to compressive and bending prestresses, some ribs were given torsional prestresses (probably the first instance of torsional prestressing in concrete).

Large new parking garage in Vancouver

Civil Engineering and Public Works Review (London), V. 54, No. 638, Sept. 1959, pp. 1022-1024

A seven-story parking garage in Vancouver, B. C., required 10,000 cu yd of concrete, 12,000 tons of reinforcing steel, and 300,000 sq ft of plywood forms. Corrugated cardboard box forms were used to form the waffle slab sections.

Construction Techniques

Concrete quality in practical construction (Die Betongute in der Baupraxis)

K. Schaden, *Der Bauingenieur* (Berlin), V. 34, No. 5, May 1959, pp. 186-191
Reviewed by Aron L. Mirsky

Surveys current experience, primarily Austrian, with quality control of concrete, particularly the large scatter found in practice, and demonstrates a few of the devices and methods developed for improving sand classification, mixing, and designing mixes.

External rendered finishes for walls

G. E. Bessey, *National Building Studies Bulletin* No. 10, Building Research Station, Department of Scientific and Industrial Research (England), 1951 (reprinted 1958), 24 pp., 3s. 6d. (available from Her Majesty's Stationery Office)

External renderings can provide a range of finishes for the walls of buildings which are pleasing and also, if certain precautions are taken, of high durability. Features can be avoided by choosing the type of finish to suit the particular requirements and by proper selection and control of the materials and their application. This bulletin discusses some of the more usual types of rendered finish and gives information on their use and specification. A section is also devoted to repairs of existing finishes.

Control testing for separation of lightweight material from aggregate

E. C. Higginson and G. B. Wallace, *ASTM Bulletin*, No. 243, Jan. 1960, pp. 60-68
Authors' Summary

A test method, developed in the U. S. Bureau of Reclamation Laboratories, for evaluating the effectiveness of large-scale separation of lightweight material from aggregate is described. Field experience using this method of test at Glen Canyon Dam is reported. The effects of the following factors on the accuracy, speed, and safety of the test are evaluated: methods of removing lightweight materials, moisture content of aggregate, rate of absorption of heavy liquid by the aggregate, and methods of washing heavy liquids from aggregate.

How to select, operate, and maintain masonry saws

Building Construction Illustrated, V. 28, No. 4, Oct. 1959, pp. 50-51

A list of 19 check points to consider for the best use of masonry saws. A table lists blades, by manufacturer, to be used with various materials.

Dams

Design and construction of the Avon Dam

James M. L. Bogle, Robert M. Ross, and Thomas McMillan, *Proceedings*, Institution of Civil Engineers (London), V. 12 (Session 1958-59), Jan. 1959, pp. 83-106, plates; discussion, Aug. 1959, pp. 601-630
Reviewed by Aron L. Mirsky

Dam, on Dartmoor, is a mass concrete gravity type 980 ft long, curved in plan (for aesthetic reasons only!) and with a maximum height of 108.5 ft. It is designed for future raising by the Coyne (stressed cable) method, the empty

ducts meantime serving as drains to relieve water pressure. Dam proper utilized Trief concrete, both to reduce heat of hydration and to save portland cement; facing was of precast block (made with ordinary cement) 2 ft deep, which also served as forms.

Hydroelectric harnessing of the Roseland gorge, Savoy (L'amenagement hydroelectrique de la chute de Roseland, Savoie)

JACQUES DUMAS, *Le Génie Civil* (Paris), V. 136, No. 5, Mar. 1, 1959, pp. 101-111
Reviewed by ARON L. MIRSKY

Ambitious scheme includes many major structures. Article describes in particular the main dam, a counterfort-type structure 150 m high with a crest length of some 800 m, and the Bathie underground power plant. This project is also described in "Das Speicherkraftwerk von Roselend-La Bathie in Savoyen," *Schweizerische Bauzeitung*, (Zürich), V. 77, No. 35, Aug. 27, 1959, pp. 563-566.

Concrete dams (Beton-Staumauern)

FRIEDRICH TÖLKE, *VDI Zeitschrift* (Düsseldorf), V. 101, No. 13, May 1, 1959, pp. 543-544
Reviewed by ARON L. MIRSKY

Latest in a series of periodic reviews of developments in design and construction of concrete dams throughout the world.

Sixth Congress on Large Dams, New York: A critical review of certain subjects

SERGE LELIAVSKY, *The Engineer* (London), V. 208, 1959: No. 5405, Aug. 28, pp. 132-134; No. 5406, Sept. 4, pp. 172-180
Reviewed by ARON L. MIRSKY

Author has selected, purely on the basis of their interest and importance to him, papers on three topics for extended discussion and evaluation: (1) flow pressure pulsation and vibration of large dams, (2) arch dam behavior, and (3) model tests for studying thermal phenomena in dams. Discussion is detailed and thorough, and obviously represents considerable study. Reviewer is of opinion more such critical reviews of the mass of material presented to engineering and scientific meetings are highly desirable.

Design

Ultimate strength of reinforced concrete in American design practice

EIVIND HOGNESTAD, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement and Concrete Association (London), 1958, pp. 593-611

Ultimate strength design procedures for reinforced concrete were recommended in the 1955 report of ACI-ASCE Committee 327. This paper discusses the background for and contents of that report. The ultimate strength method of design, including much of the Committee 327 recommendation, was then incorporated in the ACI Building Code (ACI 318-56).

Shear strength of prestressed concrete beams

RENE WALTHER, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 80-100
AUTHOR'S SUMMARY

A method is described by which the ultimate load of concrete beams can be estimated from the stresses corresponding to the rotational deformations of the failure section about the neutral axis. The theory is related to prestressed beams and web and compression reinforced concrete beams. The theoretical predictions agree reasonably well with test results.

Basic structural engineering

Bureau of Yards and Docks, Department of the Navy, Revised Feb. 1959, 132 pp., $2.75 (Order PB 151615 from Office of Technical Services, U.S., Department of Commerce)

Revised volume intended to aid firms and personnel concerned with the design, construction, and maintenance of naval shore facilities. The technical criteria apply to the principles and special features developed by the Bureau of Yards and Docks for normal, nonstandard, and prefabricated buildings. The general requirements for structural engineering are reviewed with spe-

cial attention to criteria, policy, basic design data, and design specifications. Application of the general requirements to industrial buildings, hangars, fluid storage facilities, floating structures, and structures capable of withstanding bombs, blasts, hurricanes, and earthquakes follows. The report also contains a discussion of the elements of construction including materials, fabrication, and erection.

A theory to predict the neutral surface position in rectangular prestressed concrete beams as cracking develops

H. J. Brettle, *Constructional Review* (Sydney), V. 32, No. 10, Oct. 1959, pp. 18-25

A theory is proposed relating kd, qd, and M for rectangular prestressed concrete beams. The theory is mainly concerned with conditions after cracking has commenced. The theoretical relation between applied bending moment and neutral surface position was substantiated by the observed results from 26 beams with dimensions of 4 in. x 6 in. x 10 ft. The beam factors were varied over a large range, well beyond that expected in practice.

Waterfront and harbor facilities

Bureau of Yards and Docks, Department of the Navy, Revised Feb. 1959, 124 pp., $2.75 (Order PB 151614, from office of Technical Services, U.S., Department of Commerce)

The Navy's latest technical and operational information concerning the diverse and often complex problems in the design, construction, and maintenance of harbor facilities is presented. Included are criteria covering the types and requirements of every important waterfront and harbor structure, their purposes and capacities, material and equipment best suited for construction, and the best means of assuring economical maintenance. Required criteria are given for the placement of each structure in a harbor with relation to other structures; construction, protection, and improvement of a harbor; and the actual selection of harbor sites.

New method of calculating ribbed shells (Methode nouvelle de calcul des voutes autoportantes rigides)

J. Barets, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 174-180

Author's Summary

Describes a method of calculation for ribbed shells on the basis of the theory of plane sections remaining plane and of the elimination of edge deformations by the reactions introduced by edge beams or adjacent shells. A table of transverse moments according to the various theories of support is included in the paper as well as a comparison with a test on a model.

Design of chimneys for resistance to weight and wind

Leslie Turner, *Concrete and Constructional Engineering* (London), V. 54, No. 12, Dec. 1959, pp. 395-402

Calculations for the design of reinforced concrete chimneys, somewhat a matter of trial and error, are complicated further because the effects of differences and changes of temperature have to be considered and combined with those due to the weight of the chimney and the effect of the wind. A method using charts is described whereby the stresses due to weight and wind can be readily determined. (The combination of these stresses with the stresses due to temperature has been described in *Reinforced Concrete Chimneys*, by C. P. Taylor and Leslie Turner.)

Design of reinforced concrete members

A. Aas-Jakobsen, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement and Concrete Association (London), 1958, pp. 612-625

Author's Summary

A method of design based on the principle of superposition and on the elastic theory is compared with American and European standard specifications. The method deals with the design of axially and eccentrically loaded reinforced concrete members. The eccentricity may be arbitrary; the reinforce-

ment may be symmetrical or unsymmetrical, and may also be prestressed. In the latter case the prestressing force is treated as an external load, and the design method outlined is directly applicable. The method is extended to include buckling, the coefficients ω for the increase or decrease in design load on slender members being given in the paper.

Ultimate load design of reinforced and prestressed concrete frames

A. L. L. Baker, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement and Concrete Association (London), 1958, pp. 277-304

Author's Summary

A trial and adjustment method of framework design on an ultimate strength basis, which hitherto has been described in the course of development in a number of papers by the author, is now briefly outlined as a whole.

The positions of plastic hinges and their moments of resistance are first assumed, and adjusted if necessary, until it is established that the choice of position is correct and that excessive rotations of the hinges will not occur. The method may be applied to reinforced concrete with either smooth bars or cold-worked deformed bars, or to concrete prestressed by the various systems. The strength of sections in bending is considered from first principles. Deformation calculations are based on ultimate strain values and their linear distribution. It is shown that, generally, solutions can be obtained for frameworks commonly used in practice which only entail the use of simple formulas for bending moment values combined with a check with the aid of curves of the plastic hinge rotations. The problem of shear and buckling is briefly discussed. The safe limiting values recommended in the calculations are considered, together with suitable values for the factor of safety. Such values may be varied according to the prevailing conditions, but are essentially a matter of arbitrary choice. The value of the design method must be assessed with the factor of safety conception in mind. The following points are given particular emphasis.

(1) Ultimate strength theories of bending, using equivalent stress blocks, are an unnecessary complication. The average compression strength of the concrete, the position of the center of gravity, and the linear distribution of strain at failure control the ultimate strength and ultimate deformation.

(2) The calculated ultimate strength in bending is only subject to small variation when ultimate stress, which may be obtained by nonsustained load, is assumed. It is therefore best to base the calculation of ultimate strength on the unit strength of concrete in frame members for nonsustained load for which, incidentally, unit strength generally reaches a maximum value. The ultimate strain is then approximately 0.002 for concrete above 4000 psi in strength. It is essential to limit the concrete strain to such a value to avoid high deformations resulting in excessive rotation of plastic hinges.

Determination of the design factor for reinforced concrete structures

Arne I. Johnson, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement and Concrete Association (London), 1958, pp. 25-48

Author's Summary

A necessary condition for correct design is that the total cost of a structure in deducing the principles of "statistico-economic" design of structures.

This paper contains results obtained from investigations dealing with the magnitude and the form of the standard deviations in the tensile strength of reinforcement, in the compressive strength of concrete, in the actual dimensions of a structure, and in the load. An account is given of a statistico-economic method of design. To exemplify the application of this method, it is used for designing reinforced concrete floor slabs for apartments. The results of this design are compared

with those which are obtained when the design is made in accordance with standard specifications. This comparisson shows that the use of a correct design method in the case under consideration leads to a reduction of 30 percent in the amount of reinforcement.

Load-factor design in building regulations: Future British practice

D. D. MATTHEWS, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement and Concrete Association (London), 1958, pp. 626-637

AUTHOR'S SUMMARY

Discusses the practical application of the load-factor method to the design of reinforced concrete sections which has been proposed for inclusion in the revised British Standard Code of Practice CP 114, "The Use of Normal Reinforced Concrete in Buildings." In comparison with the elastic modular ratio method, load-factor design leads to the elimination or reduction of compression steel in beams and a reduction in the reinforcement of columns subject to bending. Examples are given of sections designed by both methods.

Strength of singly reinforced beams in bending

A. H. MATTOCK, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement and Concrete Association (London), 1958, pp. 77-100

AUTHOR'S SUMMARY

The history of the subject is reviewed and it is shown that all the published theories are variants of a fundamental theory.

This fundamental theory is set down in the most general terms, and equations are developed for the depth of the neutral axis at failure and for the ultimate moment of resistance.

Experimental evidence is discussed which enables safe limiting values to be assigned to various factors introduced in the fundamental theory, such as average concrete stress at failure and maximum concrete compression strain at failure.

Using the safe limiting values arrived at, curves are drawn relating $R/\alpha u_t$ and r'. These facilitate the rapid calculation of the ultimate moment of resistance of any beam.

The calculated and experimentally determined ultimate moments of resistance for about 100 beams are compared. As a result of this comparison it is concluded that the use of the proposed safe limiting values in the fundamental theory leads to a safe estimate of the ultimate moment of resistance of any beam, whether over- or under-reinforced.

Contribution to analysis of continuous vaults (Beitrag zur Gewolbereihen-Berechnung)

M. HIRA, *Der Bauingenieur* (Berlin), V. 34, No. 3, Mar. 1959, pp. 89-91

Reviewed by ARON L. MIRSKY

Solution of continuous vaults is set up in matrix form. It is indicated that quite similar solutions occur in analysis of continuous beams, continuous frames, etc. The special case of the structure with a very large number of spans ($k \to \infty$) is investigated. A numerical example is given, involving a structure with seven spans. Superiority of matrix method is emphasized.

Some results of the theory of probability in the estimation of design loads

M. R. HORNE, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement and Concrete Association (London), 1958, pp. 3-24

AUTHOR'S SUMMARY

While uncertainties in design loads are usually much greater than uncertainties over structural behavior, comparatively little effort has been directed towards the collection of loading data. Despite this lack of information, some useful results may be obtained by applying the theory of probability to loading problems. Consideration of the probability of various loads acting together leads to a solution for the reduction in mean load intensity which may be allowed as the area under consideration is increased. The probabili-

ties of the critical combinations of side and vertical loads capable of producing plastic collapse mechanisms in a simple portal frame are examined, and it is shown how the separate probabilities of individual modes of collapse may be added to obtain the total probability of collapse. The results are examined in relation to the load factors implied in existing specifications for combined wind and superimposed loads, and it is shown that existing regulations are reasonable.

Great difficulty in assessing the significance of loads is encountered in those cases where collapse only takes place as the result of cumulative action. The theory of probability may be used to assess the danger of sufficient cumulative damage to constitute collapse, and an example of this is afforded by gust action in high winds. Cumulative damage may also arise in structures designed by the plastic theory if alternate loading distributions, each insufficient to produce static collapse, are applied a number of times. In this case the theory of probability may be used to establish the most convenient result that this phenomenon, the subject of the theory of shakedown, need not be considered as a factor in design.

The results presented in the paper, although not for the most part of great value in themselves, since only particular cases are discussed, show that considerable help may be obtained from the theory of probability in the interpretation of loading data.

Economics of framed structures

LEONARD R. CREASY, *Proceedings*, Institution of Civil Engineers (London), V. 12 (Session 1958-59), Mar. 1959, pp. 237-268
Reviewed by ARON L. MIRSKY

Costs (and weights, for steel structures) are presented for use in preliminary assessments and comparisons by designers. Covered are: simple shed frameworks, long-span roof structures, portal-frame structures, and multistory frames, with concrete becoming prominent in the last two categories. Paper includes a valuable discussion of the many factors involved, including some often forgotten or neglected. While practices and prices are of course British, translation of author's comments to American usage should be profitable and not too difficult.

Principal stresses and shear protection in reinforced concrete (Hauptspannungen und Schubsicherung im Stahlbeton)

JOSEF HAHN, *Der Bauingenieur* (Berlin), V. 34, No. 3, Mar. 1959, pp. 82-86
Reviewed by ARON L. MIRSKY

Maximum principal stresses are of critical importance in many cases, such as knees of rigid frames. This case, following Paduart's method of analysis, leads to a study of shear and shear reinforcement in beams, especially short, heavily loaded beams, and of Magnel's suggested network-type of reinforcement. Numerical examples are included. Author makes several suggestions for changes in the clauses on shear in German Standard DIN 1045.

Stresses in circular slabs and ring type foundation footings due to nonmechanical effects (Naprezenia w plytach okraglych i lawach pierscieniowych wywolane wplywami nie mechanicznymi)

J. LEDWON, *Inzynieria i Budownictwo* (Warsaw), No. 11, 1958, pp. 387-390
POLISH TECHNICAL ABSTRACTS No. 2(34), 1959

Nonmechanical effects bearing on concrete include shrinkage and temperature; these factors are of particular importance in large tanks for liquids, since tightness is the prime consideration. As regards circular slabs or ring type foundation footings, a larger amount of reinforcement due to the actual effect of nonmechanical stress has to be reckoned with, if it is assumed that, with a view to retaining the necessary tightness, the concrete should not carry tensile stresses. As follows from practice, it was assumed that nonmechanical stresses appear

even before other additional stresses. On the basis of the above assumptions, formulas were derived for stresses in a ring-shaped slab, in a round slab with a small opening in the center, and in a solid round slab. A numerical example is included.

On an invariant relation in the analysis of beams (Sur une relation invariante dans le calcul des poutres)

E. Baticle, *Le Génie Civil* (Paris), V. 136, No. 12, June 15, 1959, pp. 269-270
Reviewed by Aron L. Mirsky

For a simply supported beam of constant cross section, uniformly loaded,

$$\delta = \frac{5}{48} \frac{ML^2}{EI}$$

and

$$\frac{h}{L} \frac{\delta}{L} = \frac{5}{24} \frac{\sigma}{E}$$

where h = depth, L = span, δ = deflection, and σ = maximum fiber stress.

This is extended to reinforced concrete and prestressed concrete beams demonstrating that for equal h/L^2 and certain material properties, the deflections for prestressed concrete, reinforced concrete, and steel are in the ratios 1:2:2.5.

This is further extended to a brief investigation of the stiffening elements of suspended bridges.

Proceedings of a symposium on the strength of concrete structures

Cement and Concrete Association, London, 1958, 697 pp., L 5

This volume contains all the papers presented at a symposium held at the Institution of Civil Engineers, London, in 1956, together with the general reports and contributions to all the discussions. The contents should be of particular interest to designers because the symposium was held just after draft and/or new codes concerning the use of reinforced concrete in buildings had been issued by the British Standards Institution and the American Concrete Institute. These codes were vigorously discussed at the symposium.

The subjects covered by the symposium included: estimation of design loads, safety factors, strength of structural units under various loadings, strength of prestressed concrete members, moment redistribution, ultimate load design, dynamic loading, and many others.

Many of the individual papers will be reviewed in the ACI Journal as space permits.

Cracking of domes in unreinforced masonry (La fissuration des coupoles en maconnerie non armee)

G. Lefaudeux, *Le Génie Civil* (Paris), V. 136, No. 14, July 15, 1959, p. 310
Reviewed by Aron L. Mirsky

Stability of unreinforced-masonry domes, subject of a recent paper by P. Bouteloup in *Annales des Ponts et Chaussées* [V. 128, No. 4, July-Aug. 1953, pp. 429-503; Current Reviews, ACI Journal, V. 30, No. 9, Mar. 1959 (*Proceedings*, V. 55), p. 996] is further investigated, and it is demonstrated that proper disposition of the weight of the masonry improves the stability of cracked hemispherical domes—a method known and used by the ancients.

Torsion of open cylindrical sections. Application to reinforced concrete vaults (Torsion des profils cylindriques ouverts. Application aux sheds en beton arme)

L. Hahn, *Annales*, Institut Technique du Bâtiment et des Travaux Publics (Paris), No. 138, June 1959, pp. 575-598
Reviewed by Henri Perrin

The subject has already been treated by Timoshenko. The author exposes, in a more detailed way, the problem and its application to a reinforced concrete shed. The primary torsional stresses cause longitudinal tensile and compressive stresses, which in turn produce secondary torsional stresses. These secondary stresses may resist a high torsional moment and their omission may lead to inaccurate results.

The application of this investigation is shown in the case of an existing factory.

On the load-distribution width of concentrated and line loadings on slabs supported on two sides (Uber die Lastverteilungsbreite von Einzel- und Streckenlasten auf zweiseitig gelagerten Platten)

HUBERT BECK, *Der Bauingenieur* (Berlin), V. 34, No. 3, Mar. 1959, pp. 94-101
Reviewed by ARON L. MIRSKY

Article 19 of German Standard DIN 1045 calls for one-way slabs to be designed as slab-beams, and gives simple expressions for determining the effective width of such beams for both flexure and shear analyses. Author demonstrates that code provisions are far too oversimplified, giving results which may differ markedly from correct values (depending on relative dimensions and other factors), and that further study and revision of these provisions are necessary.

Influence of the concrete tensile stress on the stress distribution and deformation of reinforced concrete

HERBERT KRENCHEL, *Ingenioren* (Copenhagen), International Edition, V. 3, No. 4, Dec. 1959, pp. 119-123
Reviewed by JESPER STRANDGAARD

A method is described by which the concrete tensile stresses in a partially cracked, reinforced concrete section, subject to bending, can be taken into account in the computation of stress distribution and deflection. Formulas are developed for the various functions of the section with relation to the development of the cracks, and it was found possible hereby to explain some of the apparent peculiarities which regularly appear in laboratory investigations of reinforced concrete.

Contribution to the topic: Analysis of pile grids (Beitrag zum Thema Pfahlrostberechnung)

R. TROSTEL, *Der Bauingenieur* (Berlin), V. 34, No. 3, Mar. 1959, pp. 110-113
Reviewed by ARON L. MIRSKY

This short paper represents an attempt at a general solution of the problem of the three-dimensional pile grid to answer many of the points raised in a lengthy (but unpublished) correspondence discussing E. Jacoby's paper "Load Distribution on the Piles of a Pile Grid" [*Der Bauingenieur*, V. 29, No. 2, Feb. 1954, pp. 47-51; Current Reviews, ACI JOURNAL, V. 26, No. 6, Feb. 1955 (*Proceedings* V. 51), p. 581]. The existence of an elastic center is proved. Presentation is in vectorial form "for clarity."

Design of rectangular sections for oblique bending (Bemessung von Rechtekquerschnitten bei schiefer Biegung)

H. LINDNER, *Beton und Stahlbetonbau* (Berlin), V. 54, No. 7, July 1959, pp. 167-171
Reviewed by RUDOLPH SZILARD

The methods used in computing stresses caused by axial bending in two planes, is a trial and error process begun by assuming a value for the location of the neutral axis. The method developed by the author makes it possible, by means of a table, to use the same mathematical statements which are used in uniaxial bending and thereby to determine the required amount of steel and maximum concrete stresses.

Construction of large cooling towers (Construction des grandes tours de refrigerants)

A. FISCHER, *La Technique Modern Construction* (Paris), V. 14, No. 10, Oct. 1959, pp. 289-297
Reviewed by ALEXANDER M. TURITZIN

The increase in the demand for electric energy after the war necessitated the construction of large steam power plants. They were often located away from an abundant supply of water; consequently, water used for cooling condensers had to be economized and large cooling towers built to cool and recirculate it.

Towers 60 to 80 ft high became common and reinforced concrete thin shell structures were found to be the most economical form of construction for towers of such proportions.

The author develops formulas for the design of a thin shell cone subject to

wind forces and compares results with tests carried out on large scale models in wind tunnels. Close agreement was found between the theoretical and the experimental results. In conclusion a patented method of construction of cooling towers with single or double curvature, called the Faye method is described.

Several isometric sketches and pictures taken during construction illustrate the method which was successfully used in the construction of many towers of notable size.

Work of the Comite Europeen du Beton (in Swedish)

GEORG WASTLUND, *Nordisk Betong* (Stockholm), V. 3, No. 4, 1959, pp. 297-316
Reviewed by MARGARET CORBIN

The Comité Européen du Béton (CEB), organized in 1953, has approved tentative recommendations dealing with the following: safety, ultimate load design of reinforced concrete sections subjected to simple and combined flexure, and buckling of slender compression members. The assumption of a parabolic stress block is recommended. In design for buckling, the decrease in load-carrying capacity is taken into consideration by introducing an additional moment:

$$M_s = 0.3\,Nh_i\,\frac{\sigma B}{\sigma E}$$

The CEB has made extensive studies of the computation of crack widths, of a comparison of computed and test results and of allowable crack widths, but no recommendation has yet been finally approved in this connection.

Materials

Use of fly ash in building industry (in Serbian-Croatian)

P. BRZAKOVIC, *Nase Gradevinarstvo* (Belgrade), V. 13, No. 7, July 1959, pp. 149-155
Reviewed by J. J. POLIVKA

Utilization of fly ash is discussed from three different aspects: (1) in reference to existing Yugoslav standards; (2) by consideration of experiences gained in the Yugoslav building industry; (3) recommends certain foreign uses to be tried in Yugoslavia. Other materials reviewed are those that may be manufactured by addition of fly ash, including: binding materials, concrete, porous brick products, asphalt, and lightweight aggregates. Binding materials include hydraulic lime, pozzolan cements, and pozzolan-metallurgical slag cements. Use of fly ash in heavy and lightweight concrete is discussed, especially concrete produced with lime and fly ash. Experiences in brick industry confirm German investigations. Special attention is paid to the lightweight aggregates obtained by sintering of fly ash. Three types of furnaces for manufacture of this material are described. Finally, the author discusses the possibility of using fly ash in road slab construction.

Quantitative determination of the four major phases of portland cement by combined x-ray and chemical analysis

L. E. COPELAND, *et al.*, *Analytical Chemistry*, V. 31, Sept. 1959, pp. 1521-1530
BATTELLE TECHNICAL REVIEW
Dec. 1959

A method was developed for evaluating the quantities of the four major compounds or phases (tricalcium silicate or alite, β-dicalcium silicate or belite, tricalcium aluminate, and the ferrite phase) in portland cements by a combination of x-ray, quantitative, and chemical analysis.

Gap graded concrete for pavement construction

K. S. SANKARAN, *Road Research Papers*, Central Road Research Institute (Delhi), No. 23, Dec. 1958, 22 pp.

Describes the use of gap-graded concrete for pavements in areas where the locally available sands are poorly graded for purposes of the conventional continuous grading, and imported well-graded sands are too expensive for the purpose.

The investigation deals with the design of concrete mixes by using four typical sands with poor gradations, on

the gap-graded principle, wherein the gradation of coarse aggregate is adjusted after deliberately omitting certain particle sizes, so as to accommodate the available sand grading without particle interference. The study indicates that concrete mixes, designed in the above fashion, using the four typical "poor" sands, compare well with a "standard" continuous graded concrete mix in terms of strength properties. Further, these gap graded mixes seem to actually bring about a saving in cement as compared with the corresponding continuously graded mixes, thereby resulting in further economy.

Designing mixes for normal weight and lightweight concrete

JOSEPH J. SHIDELER, *Journal*, Research and Development Laboratories, Portland Cement Association, V. 2, No. 1, Jan. 1960, pp. 11-14
AUTHOR'S SUMMARY

The historical development of the basic concepts of concrete mix proportioning are briefly reviewed. The method of proportioning normal weight aggregate concrete is outlined and the reasons for the need of a separate procedure for lightweight aggregates are discussed. Means for obtaining good control of lightweight concrete under job conditions are suggested.

Compaction of tensile briquettes in cement testing: Adjustment study

Road Research Notes, Central Road Research Institute of India (Delhi), No. 9, 1957, 16 pp.

Investigations carried out to assess the comparative merits of different methods of compaction of tensile briquettes in the testing of cement revealed that the simple mechanical compactor evolved by the Hyderabad Engineering Research Laboratory gave the most uniform results. Following this investigation, further experiments were undertaken to determine the several variants in the use of this compactor suitable for testing of cement, taking into account the ease of operation, facility for reproducibility and the characteristics of the material used in the test. This report, which gives the results of the experiments, indicates the size and type of instruments to be used, the weight of the tamper, height of its drop, and the number of blows which should be adopted in the actual testing of cement. Further investigation is now being carried on to prescribe minimum tensile strength requirements for cement in India.

Coming role of pozzolans

WOLF G. BAUER, *Pit and Quarry*, V. 51, No. 12, June 1959, pp. 92-97, 101; V. 52, No. 1, July 1959, pp. 89-91, 96; V. 52, No. 3, Sept. 1959, pp. 107-110

Evaluates factors which might influence the establishment of a recognized pozzolan industry. Advantages in the use of pozzolans are presented in a general, nontechnical manner. Part 2 has an interesting chart showing the relationships of various materials suppliers, trade associations, and technical societies in the concrete field. Part 3 consists of a bibliography on the subject extending from 1899 to 1959.

Damaging reactions in concrete

Engineering (London), V. 187, No. 4846, Jan. 23, 1959, p. 128
Reviewed by ABON L. MIRSKY

Report of two cement-aggregate-reaction cases studied by the Materials Section of the Division of Building Research, National Research Council, Ottawa.

First case concerns a concrete bridge deck which expanded so much the expansion joints closed up and required resetting every 6-8 years of the total life span of 25 years. Fortunately, the aggregate in this case is no longer being used.

The second case, at Kingston, Ontario, involves a limestone which is the only locally available coarse aggregate. Much of the local concrete exhibits map crazing, especially concrete in contact with ground moisture (footings, pavements, etc.). The cause was found to be reaction between the limestone and the alkali in the cement; however,

the same limestone causes no difficulty when used with low-alkali cement. The problem is exacerbated by the fact the limestone does not respond to the usual tests for reactive aggregate, nor to the admixtures that proved to be effective in this case. The investigation is continuing, with the purpose of developing rapid methods for identifying reactive limestones (at present, a minimum specimen-conditioning period of at least 6 months is required for evaluation of the Kingston limestone).

Pavements

Principles of pavement design

E. J. YODER, John Wiley & Sons, Inc., New York, 1959, 589 pp., $13.25.

This book sets forth some of the basic factors which must be considered in dealing with design of pavements and presents applications of principles involving the basic factors to design problems. The author brings together various concepts of design and information published by many agencies: ACI, Bureau of Public Roads, American Association of State Highway Officials, Asphalt Institute, Federal Aviation Agency, Corps of Engineers, Highway Research Board, and state highway departments. Since it is assumed that the reader has a prior basic knowledge of soil mechanics and concrete mixes, the book is primarily intended for use in a graduate course on pavement design but can be applied in part to undergraduate courses.

The text material as divided into five parts, gives a realistic detailed approach to pavement design, both rigid and flexible, for highways and airfields. Part 1 deals with fundamental principles, describing first the pavement types and then working into stresses in the pavements based on wheel loads; the effects of climate and subgrade on life and design considerations of the pavement are explained. Part 2 explains the properties of pavement components, dealing primarily with soils, starting first with the classification systems for soils and methods of evaluating soil strength, then working into design considerations for subgrades, soil stabilization, construction methods, and design tests. Part 3 is restricted to the design of flexible pavements and covers both airport and highway pavements. Part 4 similarly deals with rigid pavements as applied to airports and highways but in addition devotes one chapter to the design of joints which is a primary factor in the design of rigid pavements. Finally, Part 5 which covers pavement evaluation and strengthening discusses the methods of studying and surveying existing pavements for performance, road life studies, etc., and gives methods and principles of maintaining and strengthening existing pavements.

Wire and pin anchorages permit pretensioning tendons in place

Engineering News-Record, V. 163, No. 25, Dec. 17, 1959, pp. 58-60

Extension of Schwechat Airport, Vienna, uses pretensioned concrete, prestressed in place. Anchor blocks 4 x 10 ft are cast at 412-ft intervals; each is cast with ten pairs of anchor pins and 80 prestressing wires. Each wire is tensioned to 4848 psi. Slabs are post-tensioned in the transverse direction, and are 4 in. thick with a 2 in. integral wearing course.

Construction of a prestressed concrete test pavement

CARL F. RENZ, *Proceedings*, ASCE, V. 85, AT 4, Oct. 1959, pp. 25-39

AUTHOR'S SUMMARY

The construction of a full scale prestressed concrete pavement which is to be subjected to controlled traffic testing is described. The pavement was post-tensioned, using high tensile strength steel bars encased in steel tubing and grouted. The method of partially tensioning the tendons to insure proper alignment during concrete placement is outlined as is also the method used to complete the tensioning of the tendons.

Precast Concrete

Reinforced concrete floors and roofs with clay hollow block system SAT (in Slovene)

L. J. Skaberne and L. Treppo, *Gradbeni Vestnik* (Ljubljana), V. 10, No. 61-64, 1958-1959, pp. 22-26

Reviewed by J. J. Polivka

Describes the prefabrication of straight and curved roof units, their design, and erection. Results of concentrated load tests (with units about 15 ft long) are recorded. These units are applied to a factory building with a circular roof spanning 44 ft and with two flat roofs on each side having 20-ft spans.

Prestressed Concrete

Continuous prestressing elements and methods of fabrication (Elements en beton precontraint par fil continu et methodes de fabrication)

G. Berditchevski, A. Svetov, and B. Sklyar, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 535-549

Author's Summary

Describes mechanized systems of positioning prestressing wires whereby all the wire in a given structural part is in a single length. This is achieved by the use of rotary platforms on which the elements being produced are mounted and devices that feed the wire under tension. Alternatively, the wire is given turns round pins which are set in the molds and subsequently extracted. Anchorage is provided by the bond.

Calculation of prestressed bases of circular cylindrical tanks (Berechnung der Bodenplatten von kreisformigen Zylinderbehaltern aus vorgespantem Beton)

S. Svoboda, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 158-164

Author's Summary

Although the prestressing of walls and domes of cylindrical tanks has been studied quite thoroughly, less attention has been paid to the prestressing of the bases. This is probably due to the difficulty of finding an exact solution. The author discusses the method of calculating prestressed circular plates developed by Havelka which makes it possible to design prestressed bases for tanks with precision, safety, and economy.

Tests of short prestressed concrete beams and recommendations (Vorschlage zur Auswertung und Beurteilung von Bruchversuchen an kurzen Spannbetonbiegebalken)

H. Wittfoht, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 38-46

Author's Summary

Proposals are made for the interpretation of the results of ultimate flexural strength tests on short prestressed concrete beams, in both the static and the dynamic fields. The tests provide data concerning the increases in the stress in the steel due to the live load, the weakening of the bond, the magnitude of the bond stresses, the transmission length, and the thrust and shear forces at the ends of the beams.

Stress redistribution caused by creep and shrinkage by multistrand prestressing (Spannungsumlagerung durch Schwinden und Kriechen bei mehrstrongiger vorspannung)

H. Reiffenstuhl, *Beton und Stahlbetonbau* (Berlin), V. 54, No. 7, July 1959, pp. 172-173

Reviewed by Rudolph Szilard

The stress reducing effects of creep and shrinkage, for the case of prestressing by two strands, are computed by assuming that the grout produces complete bond between concrete and strands.

Prestressed concrete construction in mines under pressure (Spannbeton im Druckstollenbau)

H. Kastner, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 181-191

Author's Summary

The application of prestressed concrete to the driving of galleries in mines under pressure is possible either in the

usual manner with steel prestressing tendons or with the thrust being taken by the rock. The latter method is here treated theoretically with particular reference to the *Kernringbauweise* invented in Austria. The results of the theoretical investigations permit a critical estimate of this method.

Limit design of prestressed concrete in the URSS (Calcul des constructions en beton precontraint en URSS d'apres la methode des etats limites)

A. A. Gvozdev, S. A. Dmitriev, B. A. Kalatourov, and V. V. Mikhailov, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 208-219

Author's Summary

A brief exposition of a new theory on which to base prestressed concrete design. So far the factor of safety has been almost invariably referred to ultimate failure — but other contingencies may render a structure unserviceable, such as lack of rigidity, the formation of cracks, and so on. Therefore it has been thought to make use of several differentiated factors in accordance with the various conditions governing prestressed concrete design.

Ultimate strength design of prestressed concrete members

G. C. Reynolds, *Commonwealth Engineer* (Melbourne), V. 47, No. 1, Aug. 5, 1959, pp. 68-69

Presents method for calculating the ultimate strength of prestressed concrete members. Basic assumptions are that strains vary linearly across the section, and that concrete fails in compression when it reaches a strain of 0.003.

Transmission of prestress to concrete by bond

E. H. Ratz, M. M. Holmjanski, and V. M. Kolner, *Proceedings*, Third Congress, Fédération de la Précontrainte, Berlin, 1958, pp. 624-640

Author's Summary

A series of tests on approximately 200 test samples give the data for a quantitative estimate of how bond is affected by the strength of the concrete and the deformation and surface condition of the wires, of which 18 types were tested. It was found that the bond is a direct function of the strength of the concrete for any given type of concrete and wire. On the basis of a direct relation between the tension in the wire and its displacement within the anchorage zone, a formula has been developed and experimentally verified for the movement of the wire at any point of its length. The conclusions give certain recommendations concerning the strength of concrete at which to transfer the prestressing force and the choice of deformation for the wires.

Technical problems in the use of glass fiber as reinforcement for prestressed concrete (Technische Probleme bei der Verwendung von Glasfaser als Bewehrung fur Spannbeton)

Stanislaw Kajfasz, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 436-450

Author's Summary

Discusses the technical problems arising from the use of glass fiber instead of steel cables for prestressing, such as the increase in the area of the section, loss of stress due to relaxation, and the difficulty of secure anchorage. The influence of the bond on the cracking characteristics of the structure is also studied and the paper concludes with comparative results of the test loading of pretensioned and post-tensioned beams.

Stability of structures prestressed by hooping

C. Eimer, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 165-173

Author's Summary

The paper considers the problem of buckling in containing structures, such as tubes and tanks, which tend to buckle when empty, owing to the force exerted by the prestressing itself. The solution assumes linear elasticity of the material and is based on the nonlinear

theory of thin bars, while ignoring the effect of shear forces and the deformations due to axial compression. It has been ascertained that a nondeformed circular structure is inherently stable for all finite values of the prestressing and that it may pass to the deformed state of equilibrium under the effect of initial deformations of finite magnitude. The result is in the form of elliptic integrals and approximate equations are developed from a general theory for both the critical force and the minimum thickness in regard to various materials.

The design of prestressed continuous beams with variable moment of Inertia taking into consideration the variability of the prestressing force along the beam (in Polish)

WLODZIMIERZ STAROSOLSKI, *Archiwum Inzynierii Ladowej* (Warsaw), V. 5. No. 3, 1959, pp. 347-373

Reviewed by STEVEN GALEZEWSKI

Presents a general method of design for prestressed continuous beams with variable moments of inertia. The variability of the prestressing force along the beam and the variability of losses of prestress are considered. All stages of loading including transfer, dead load, and live load are discussed. Criteria for the choice of the critical state as well as all equations necessary for the design are given. A numerical example follows the presentation of the theory.

Basis for an international standard for prestressed concrete (Bases d'un reglement international concernant le beton precontraint)

A. PADUART, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 220-227

AUTHOR'S SUMMARY

By comparing various regulations the author seeks a basis for an international standard for prestressed concrete. He examines in turn the quality of the concrete and of the steel, the allowable compression and tensile stresses in concrete under the effect of bending and shear, the allowable tensile stress in the prestressing wires, the factors of safety for both cracking and failure, losses of prestress, buckling, anchorage of the cables, and the protection of the wires.

The author hopes that various countries will express their views on the standards, which will make it possible to decide whether international standardization can be achieved.

Design theory for centrally loaded columns of pretensioned prestressed concrete (Berechungstheorie der achsial gedruckten Saulen aus Stahlsaitenbeton)

TOMASZ KLUZ, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 228-234

AUTHOR'S SUMMARY

Some tests on centrally loaded columns are described. These columns were made of pretensioned prestressed concrete or were reinforced with pretensioned precast planks. The ultimate loads of the columns were from 40 to 80 percent higher than the values calculated by the usual methods.

The author believes that the higher loadcarrying capacity can be explained by the existence of a triaxial state of stress in the prestressing steel of the loaded colums, and he derives equations for determining the stresses in the concrete and steel.

Control of prestressing in the construction of de Tancarville Bridge (Le controle d'execution de la precontrainte sur le chantier du Pont de Tancarville)

G. DREUX, *Proceedings*, Third Congress, Fédération Internationale de la Précontainte, Berlin, 1958, pp. 376-391

AUTHOR'S SUMMARY

Describes some measurements of friction on the site and refers in particular to some measurements of elongation in the course of which he had noticed a "deferred elongation" probably due to increased friction when tensioning begins. A method is given of computing the total elongation avoiding errors due to this phenomenon.

Prestressed concrete building production in Sweden

HENNING COLLBORG, *Journal*, Prestressed Concrete Institute, V. 4, No. 3, Dec. 1959, pp. 18-32

AUTHOR'S SUMMARY

The development of factory produced prestressed concrete in Sweden is outlined, and five typical buildings are described: (1) a streetcar garage, (2) a single-story industrial building, (3) a three-story department store, (4) a five-story -industrial building, and (5) a 14-story office building. Details of connections, between precast members are emphasized, and adaptation for factory production is discussed.

High-strength wires for prestressed concrete (in Serbian-Croatian)

D. JEVTIC, *Nase Gradevinarstvo* (Belgrade), V. 13, Part I, No. 5, May 1959, pp. 112-122; Part I, No. 6, June 1959, pp. 132-139

Reviewed by J. J. POLIVKA

Thoroughly discusses the properties of prestressed wires used in Yugoslavia and compares them with standards used in other countries, especially the United States, France, Germany, Belgium, and Russia. Test results obtained from the Institute of Material Testing, Belgrade, are recorded and compared. Especially emphasized is the loss of strength due to twisting, increase of temperature (up to 200-400 C), and corrosion. Methods on how to prevent or reduce these losses are described. Of special interest are data on physical properties of prestressed wires in structures exposed to fire.

Preparation and durability testing of pretensioned prestressed concrete

STANLEY LEE RIEB, *Journal*, Prestressed Concrete Institute, V. 4, No. 3, Dec. 1959, pp. 102-146

The investigation reported was fundamentally concerned with the durability of prestressed concrete in regard to freezing and thawing action. Some provisions were made to study the creep in the loaded concrete specimens. A lengthy discussion concerning preparation of the test specimens is included. Results presented are concerned primarily with only two series of specimens.

The soundness of all beam specimens, after being subjected to between 400 and 800 fast freezing and thawing cycles, was satisfactory. The effects of the introduced variables (level of stress in the concrete, type of cement, and method of curing) on the durability of the concrete could not be differentiated.

Report on differential shrinkage in composite prestressed concrete beams

D. E. BRANSON and A. M. OZELL, *Journal*, Prestressed Concrete Institute, V. 4, No. 3, Dec. 1959, pp. 61-79

This investigation studied, both experimentally and analytically, the effects of shrinkage and creep in composite construction consisting of a prestressed concrete beam and cast-in-place slab. The term "differential shrinkage" is used here for the effect of the relative strains in the two concretes caused by the shrinkage of the cast-in-place concrete and shrinkage plus creep of the prestressed concrete when the two are bonded together.

The strain distribution diagrams corresponding to the differential-shrinkage stresses do not necessarily have the same slope in each portion of the composite beam. The differential-shrinkage force produces moments about the centroid of each section in the composite beam, and this combined moment and longitudinal force induce stresses in each section as determined by the properties of the individual section itself, and not by a transformed composite section.

The stress distribution resulting from differential shrinkage and slab dead load cause a creep distribution different from that of the same beam without the cast-in-place slab. However, at the center of gravity of the prestressed steel this change in stress is very small so that the change in creep at that point—and thus the change in prestress

loss because of the change in concrete creep—is negligible in the composite beam. Hence the loss of prestress from concrete creep is not altered from that of a noncomposite beam by the slab dead load or differential-shrinkage effect.

The procedure developed herein provides a simple method for calculating the stresses resulting from differential shrinkage, if an appropriate differential-shrinkage coefficient is known. For design purposes it is believed that this coefficient can be prescribed for a given estimated period of time between casting of the two concretes. Additional information is needed on this and other aspects of composite differential shrinkage.

Prestressed concrete structure for an apartment building

K. L. Albert, *Proceedings*, Second National Prestressed Concrete Conference, Wellington, New Zealand, 1958, pp. 94-98
Author's Summary

A summary of considerations taken into account when designing and constructing a three-story block of ten residential flats. The super-structure consists basically of flat slabs resting on bearing walls all of which have been cast in place and post-tensioned.

Research on shear-carrying capacity of prestressed concrete beams made of prefabricated elements (Versuche uber die Querkraftaufnahme in Fugen von Spannbetontragern aus Fertigteilen)

Gotthard Franz, *Beton und Stahlbetonbau* (Berlin), V. 54, No. 6, June 1959, pp. 137-140
Reviewed by Rudolph Szilard

The disadvantage of prefabrication, compared to its many advantages, is its limited length and the problems of connecting elements. Moments can be transferred relatively easily by means of post-tensioning while the shear forces are carried by shear and bond; the effects of which are not fully known. To test the shear-carrying capacity, high quality prefabricated concrete cubes have been connected together by post-tensioning. Transverse shear forces were then applied by hydraulic jacks. By this process flat joints and joints with keys were tested. The test results show that friction carries a large part of the ultimate shear load, which is approximately 55-70 percent of the longitudinal tensile force.

Deflection theory for rectangular prestressed concrete beams after flexure cracking has commenced

H. J. Brettle, *Journal*, Prestressed Concrete Institute, V. 4, No. 3, Dec. 1959, pp. 80-101
Author's Summary

A theory for deflection of prestressed concrete beams is proposed which applies from the onset of cracking up to the load that produces nonlinear stress distribution in either the concrete or the steel. Prior to cracking, Navier's fundamental differential equation for deflection is applicable.

Experimental tests were carried out on twenty-six 6 in. x 4 in. x 10 ft pretensioned beams subjected to a large range of initial concrete prestress, from 30 percent to 300 percent of that normally used in practice. The beams were tested to failure at age of about 36 days by the continuous application of incremental loading. Good correlation between the observed deflections and those calculated from the proposed theory were obtained.

Prestressed concrete in relation to seismic effects

Y. Guyon, *Proceedings*, Second National Prestressed Concrete Conference, Wellington, New Zealand, 1958, pp. 129-136

A method is presented for the designing of multistory buildings, taking into account seismic forces. Briefly explains and discusses a method of calculating stress in a multistory building under vertical loads, assuming that the joints are fixed. Multistory buildings under horizontal forces are discussed and the author sets down an eight-step solution. The paper concludes with a discussion of dynamic design. (This report is a brief summary of a complete

paper for which the full text is available from the Secretary of the Second National Prestressed Concrete Conference, Wellington, New Zealand).

Recommendations regarding friction in straight and curved members (Vorschlage zur genaueren Erfassung der reibungsbedingten Spannkraftverluste in gereden und gekrummten Spannliedern)

BERNHARD FRITZ, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 392-406

AUTHOR'S SUMMARY

Discusses the various causes of friction and develops the results of experiments into recommendations for both applying the coefficient when designing and choosing materials and methods of reducing friction.

Proceedings, Second National Prestressed Concrete Conference

Second National Prestressed Concrete Conference, Wellington, New Zealand, 1958, 144 pp., $3

A collection of 22 papers covering various aspects of prestressed concrete design, materials, construction, and the use of prestressed concrete in various precast products and structures. Various individual papers will be reviewed in the Current Reviews section as space allows.

Properties of Concrete

Analysis of the elastic properties of concrete by means of ultrasonic waves (Untersuchung der elastischen Eigenschaften von Beton mittels Ultraschall)

K. EISENMANN and G. ODEWALD, *Beton und Stahlbetonbau* (Berlin), V. 54, No. 6, June 1959, pp. 156-158

Reviewed by RUDOLPH SZILARD

Standard test methods indicate there is a difference between static and dynamic modulus of elasticity of concrete. To investigate the reason for this difference, concrete test specimens have been exposed to ultrasonic waves in the longitudinal direction and the velocity of these waves were then measured under both static and dynamic (impulse) loading. The result of the test is: that the hypothesis which states that the static modulus of elasticity follows Bach's formula while the dynamic modulus is the same at all loadings, is not valid. This new investigation indicates that the difference between E_s and E_d is insignificant for all practical purposes.

Creep of lightweight concrete

C. H. BEST and M. POLIVKA, *Magazine of Concrete Research* (London), V. 11, No. 33, Nov. 1959, pp. 129-134

AUTHORS' SUMMARY

Creep data covering periods of up to 18 months for concretes made with expanded shale aggregates and having compressive strengths of 3000 and 5000 psi at 28 days are reported. These are compared with data for sand-gravel concretes of comparable strength. It was found that, contrary to current opinion, creep in lightweight concrete was essentially equal to or less than that in normal-weight concrete of comparable strength.

A brief description of the hydraulic loading equipment used in the creep tests is included. The equipment performed satisfactorily throughout this investigation with little maintenance; it may be expected to perform similarly at any stress level normally encountered in creep studies. Some brief comments relative to the merit of current techniques for studying creep in concrete are made, and a new approach to the problem is suggested.

Analysis of deformation and failure characteristics of concrete

A. L. L. BAKER, *Magazine of Concrete Research* (London), V. 11, No. 33, Nov. 1959, pp. 119-128

AUTHOR'S SUMMARY

The paper shows that the aggregate grading and compaction required for strong concrete produce an internal structural system which approximates a series of lattices in two directions and at right angles to each other. The diagonal members of the lattice are stiffer than the cross members, which represent the mortar in the "voids," bonded to the diagonal members. The idealized system is analyzed in terms of the rela-

tive stiffness of the lattice members, and equations are derived and curves plotted from which Poisson's ratio is related to stiffness ratios for various values of the ratio of axial compression to transverse tensile strength. The curves give a reasonable explanation of changes in Poisson's ratio and compressive strength due to changes in the secant elastic modulus of mortar due to creep.

The paper also introduces a useful model technique by which the internal structural system of concrete can be represented. Ordinary draper's elastic is used to form a lattice having members of appropriate relative stiffness. The elastic is prestressed to prevent buckling. External compression acting on concrete specimens may be studied as external tension on the model, since changes of internal stresses and strains are sufficient to indicate internal distribution. Such models may be used to obtain the distribution of maximum tensile stresses in a concrete specimen under test, and hence the crack pattern and mode of failure for various shapes and external restraints.

Effect of water absorption by aggregates on the water-cement ratio of concrete

K. NEWMAN, *Magazine of Concrete Research* (London), V. 11, No. 33, Nov. 1959, pp. 135-142

AUTHOR'S SUMMARY

Tests were made on damp and dry aggregates to discover how the definition of "effective water-cement ratio" is affected by aggregate absorption. Analysis of the results indicates that mixes with saturated river gravel aggregates give higher strengths and compacting factors than supposedly similar mixes made with dry aggregates. The coating of cement paste considerably reduces the rate of absorption, which ceases when paste hardens.

The effective water-cement ratio for strength should be based on the free water content available when the paste hardens. This is known more accurately when saturated aggregates are used. For dry aggregates, crushed rock material becomes saturated to the same degree as after immersion in water for 30 min., but for uncrushed river gravels the degree of saturation depends on the amount and consistence of the cement paste.

The effective water-cement ratio for workability is more difficult to define. It can be assumed, provisionally, that initially dry aggregates will have achieved, at the time of the workability test, the same degree of saturation as they would have in water.

These effects of absorption only apply to high-strength mixes. Rich, uneconomical site mixes can be avoided if laboratory trials are based on the effective water-cement ratio as defined in this paper.

A possible mechanism for carbonation shrinkage and crazing, based on the study of thin layers of hydrated cement

K. M. ALEXANDER and J. WARDLAW, *Australian Journal of Applied Science* (Melbourne), V. 10, No. 4, Dec. 1959, pp. 470-483

AUTHORS' SUMMARY

The carbonation of hydrated portland cement paste was studied under conditions which required a penetration of only 0.06 in. for complete carbonation. The results were obtained by drawing a slow stream of CO_2-free air, or air with its normal content of CO_2, over the specimens for 9 months. The relative humidities of the curing atmospheres were controlled at various levels within the range 0-100 percent, and the experiments were repeated using atmospheres of 100 percent CO_2. Under the present conditions of the experiment, the shrinkage caused by complete carbonation was found to be approximately equal to the long-term drying shrinkage upon which it was superimposed. At all intermediate stages of carbonation, the carbonation shrinkage was linearly related to the degree of carbonation. The degree of carbonation made possible by prolonged exposure to atmospheres containing either high or low concentrations of CO_2 depended not only on the concentration of CO_2, but also on the relative humidity. The evi-

dence suggests that carbonation shrinkage can be regarded, in effect, as a form of drying shrinkage made possible by the release of nonevaporable water from the hydrated paste as a result of the reaction with CO_2. Finally, regarding the question of carbonation crazing and cracking, it is suggested that these effects are not directly caused by carbonation shrinkage, but result from the formation of a brittle layer of carbonation products at the surface of the specimen, which layer subsequently crazes as drying shrinkage and carbonation shrinkage continue.

Failure of concrete under compound stress

A. J. Harris, *Proceedings of a Symposium on the Strength of Concrete Structures*, Cement ment and Concrete Association (London), 1958, pp. 201-218

Author's Summary

Describes a new theory of rupture of concrete, in which conceptions are applied which are more common in the theory of soil mechanics; the two parameters which express the strength of concrete in this theory are the cohesion and the angle of internal friction.

The application of the theory to basic types of failure—in compression, in tension, in shear, and in compound stress —is investigated and the results compared with experience.

A statistical hypothesis for rupture in concrete (in Danish)

Steen Lichtenberg, *Nordisk Betong* (Stockholm), V. 3, No. 4, 1959, pp. 317-336

Reviewed by Margaret Corbin

The article examines concrete strength in its relation to stress condition, as commonly represented in terms of Mohr's envelope. Among the various theories of rupture, the *friction hypothesis* seems best adapted to concrete, but its application nevertheless yields a considerable scatter in test results. The author attempts to establish a relation of this scatter to heterogeneity, i. e., extend the theory of friction to apply to heterogeneous or porous materials. Statistical theories of rupture, advanced by Daniels, Weibull, A. I. Johnson and others, are reviewed. A formula expressing the friction hypothesis is presented. The friction hypothesis extended in this manner can be used to analyze allied phenomena of rupture, such as great uncertainty in measurements of ultimate strain.

Evaluation of Poisson's ratio and the modulus of materials of a low tensile resistance by the Brazilian (indirect tensile) test with particular reference to concrete

G. Hondros, *Australian Journal of Applied Science* (Melbourne), V. 10, No. 3, Sept. 1959, pp. 243-264

Author's Summary

The Brazilian or indirect tensile test is a convenient and established technique for the assessment of the tensile strength of concrete, a material which, because of its low tensile resistance, presents testing difficulties with which conventional methods cannot cope. This paper describes the analysis of the circular specimen loaded to conform to the accepted practical recommendations for the Brazilian test, and its extension to yield a direct method of evaluating Poisson's ratio and the modulus of cement mortars and concrete. Steel specimens were employed to assess the validity of the experimental techniques and to select an acceptable specimen shape for use in destructive tests on concrete.

Influence of the type of cement, of water-cement ratio, and of the age at the time of load application on the creep of concrete (Vom Einfluss der Zementart, des Wasserzementverhaltnisses und des Belastungsalters auf das Kreichen von Beton)

A. Hummel, *Zement-Kalk-Gips* (Wiesbaden), V. 12, No. 5, May 1959, pp. 181-187

Reviewed by H. H. Werner

Research establishes: (1) for lower cement content and hence lower concrete strengths the creep values are larger than for higher standard strengths; (2) for increased water-cement ratios the creep values increase, particularly at advanced ages; (3) higher creep values result with

earlier application of sustained loading, reaching a virtually unchanged maximum when applied at 28 days or later; (4) in consequence of marked reduction of the compressive strength with advancing age, the creep values for concrete made with high-alumina cement again increase considerably from 1 year on; (5) creep values measured after 3 years are in good practical agreement with the final creep values that Ross has predicted by calculation; (6) specific creep values are dependent on the pore space of the hardened cement-stone (pore space of the solidified cement paste), on the compressive strength of the concrete at the time of load application, and on the compressive strength of the concrete at the time of measuring the creep. A formula has been established for this.

Economy of cement achieved by taking into account the increase in strength of concrete with time

I. P. Gvodarev and M. V. Vershinin, *Beton i Zhelezobeton* (Moscow), No. 7, July 1959, pp. 292-294

Reviewed by D. Watstein

The Russian specification governing construction of monolithic hydraulic structures, GOST 4286-48, have recently been revised to permit the use of concrete mixes which attain the specified compressive strengths at those ages when the structure is actually loaded. To furnish the construction industry with a guide, the Institute for Concrete and Reinforced Concrete prepared a table of conversion coefficients by which the 90-day and 180-day strengths may be estimated from the 28-day strengths. These coefficients were prepared for cements of four types. The classification of the cements was based on the content of aluminates and tricalcium silicates, and also on the presence of pozzolanic and slag material.

The table indicates that in most cases cements used in monolithic construction assure an increase of 26 to 80 percent over and above the 29-day strength at 6 months.

Structural Research

Aerodynamic studies, I: Hyperbolic cooling tower (Etudes aerodynamiques, I :Tour de refrigeration hyperbolique)

R. Pris, *Annales*, Institut Technique du Bâtiment et des Travaux Publics (Paris), No. 134, Feb. 1959, pp. 147-167

Reviewed by Henri Perrin

Drag values and wind pressures at various levels of a hyperbolic tower are given in a detailed way. Tests have been conducted with rough and smooth surfaces and the variations recorded. Some internal pressures were also measured as well as forces applied on the supports. Study of smoke streams shows no downward wind at the upper level.

Aerodynamic studies, II :French Pavillon at the Brussels Fair, 1958 (Etudes aerodynamiques, II :Le Pavillon de la France a l'Exposition de Bruxelles, 1958)

R. Pris, *Annales*, Institut Technique du Bâtiment et des Travaux Publics (Paris), No. 137, May 1959, pp. 407-420

Reviewed by Henri Perrin

The French Pavillon was bearing mainly on three points and the exact measurements of the wind forces for four wind directions were undertaken on a 1/125 scale model. Study by means of smoke streams was also conducted. The tests were performed, at first, with no walls, then with only three, and finally with all four walls.

Studies in composite construction. Part 1 — The composite action of brick panel walls supported on reinforced concrete beams

R. H. Wood, *National Building Studies Research Paper* No. 13, Building Research Station, Department of Scientific and Industrial Research, London, Reprinted 1957, 32 pp., 2s. 8d.

The tests described were carried out originally to determine the most economical design of foundation beams which are required to support the brick walls of houses, schools, etc., when the whole of the building is carried on short bored piles spaced at regular intervals.

This paper is restricted to producing simple design rules which are safe and economical for reinforced concrete beams supporting permanent brick walls with and without openings. The design recommendation should be applicable to lintels and no doubt to any beam of a reinforced concrete frame which carries brick walls, provided that most of the load is due to the weight of the wall itself and the superimposed load on the wall.

Rectangular staircases without beams

J. F. Borges, *Technical Paper* No. 121, Laboratorio Nacional de Engenharia Civil, Ministerio de Obras Publicas (Lisbon), 1958, 13 pp.

Applied Mechanics Review Jan. 1960

The results of model and prototype tests on rectangular staircases composed of slabs without beams are presented. Design methods for this type of stairs are discussed. Such discussion is based on the interpretation of the experimental results. It is shown that to solve the problem it is especially important to determine the vertical deformability of the intersection line of the flight and landing slabs.

An investigation into the cause of cracking in a reinforced concrete silo containing cement

R. E. Rowe, *Magazine of Concrete Research* (London), V. 11, No. 32, July 1959, pp. 65-74

Author's Summary

Describes a series of tests carried out to determine the cause of cracking in a reinforced concrete silo used for storing cement. The tests covered the location of the steel reinforcement and the measurement of the laps in the horizontal steel, the pressures exerted on the walls, and the temperature differential through the walls.

The cause of cracking was a combination of the effects of pressure in excess of that designed for, large temperature differentials through the walls of the silo, and a deficiency in reinforcing steel.

From the results obtained it is clear that Janssen's theory for the pressure exerted by granular materials on the walls of a container is unapplicable to cement. An alternative method of determining the pressures, based on the experimental results, is put forward. The temperature differential through the walls was about 33 C during the tests and indicates that this factor must be considered in the design of a cement silo.

Finally the need is stressed for further tests on actual cement silos so that a more realistic method of design can be evolved.

Structural fire protection of buildings with special reference to reinforced concrete

F. S. Hespe, *Constructional Review* (Sydney), V. 32, No. 7, July 1959, pp. 18-29; No. 8, Aug. 1959, pp. 18-27

Author's Summary

Fire protection, or more specifically, structural fire protection as distinct from fire fighting services and appliances, depends not only on the fire resistance rating of structural members but on whether the rating is that required for the complete protection of a particular building. Buildings may be classified according to their occupancy, e.g., office buildings, warehouses, factories, etc.; and the likely severity of a fire in each occupancy class expressed in terms of BTU's per sq ft. This expression is called the fire load. The fire load for different occupancies has been shown to be equivalent in severity to certain periods of the Standard Fire Test, e.g., 100,000 in the Standard Fire Test. This fact provides the necessary link between the fire resistance requirements of buildings and the fire rating of structural members.

The fire resistance rating of elements can be based on *ad hoc* testing of sample specimens or on the findings and recommendations of authoritative research bodies. There is no question that, with the possible exception of precast units, the fire rating

of concrete members must be based on such recommendations, derived no doubt from test results, but nevertheless subject to certain reservations and the possibility of doubt. Insufficient test data are available for a statistical analysis to be carried out, but the authorities at the Joint Fire Research Station at Elstress, Herts (England), have analyzed the results of tests carried out at this station in the light of their experience and observation of the tests.

This, and later tests and analyses have formed the basis for various British recommendations and codes, culminating in the latest British Concrete Code (CP.114-1957), which may be regarded as embodying in its recommendations for fire resistance ratings, the latest thought and test results from the foremost authority in the world on fire testing, the Fire Research Station at Elstree. A mathematical analysis can provide a useful guide, if the necessary assumptions are not overlooked. The recommendations in CP.114 for columns with mesh in the cover are in fact similar to results obtained from such an analysis.

General

Laboratory investigation of rubble-mound breakwaters

ROBERT Y. HUDSON, *Proceedings*, ASCE, Vol. 85, WW3, Sept. 1959, pp. 93-121

AUTHOR'S SUMMARY

A laboratory investigation is being conducted at the U. S. Army Engineer Waterways Experiment Station to determine criteria for the design and construction of rubble-mound breakwaters. Smallscale breakwater sections are hand constructed in a concrete wave flume 119 ft long, 5 ft wide, 4 ft deep, and subjected to mechanically generated waves to determine the stability of the armor units.

A general stability equation has been derived and is being used to guide the experimental program and correlate the test data. From the test data obtained to date, important unknown functions in the general stability equation have been determined for selected breakwater and test-wave conditions, and a new breakwater stability formula has been obtained.

In conjunction with the stability tests, wave run-up data are obtained for each breakwater section and wave condition tested. Also, measurements are obtained that enable the thickness and porosity of cover layers composed of different types of armor units to be determined.

The new stability formula and the experimental data obtained so far have provided essential information for an improved method of designing rubble-mound breakwaters with protective cover layers composed of quarry-stone and tetrapod armor units. Tests now in progress to obtain experimental data for other special shapes of cast iron concrete armor units (cubes, tetrahedrons, and tribars) should increase considerably the accuracy of rubble-mound breakwater design.

Construction of nomograms

W. E. SCRIVEN, *Concrete and Constructional Engineering* (London), V. 54, No. 8, Aug. 1959, pp. 263-272

Brief instruction on the making of nomograms. Types included are charts from empirical data and from mathematical equations. An example shows the construction of a nomogram giving the relationship between strength of 6-in. cubes of concrete, age, and water-cement ratio.

Which shall it be: your own or commercial testing facilities?

Concrete Products, V. 62, No. 9, Sept. 1959, pp. 42-47

Emphasizes the need for testing to ensure good concrete whether private or commercial. A brief outline of several tests needed in the day-to-day process of manufacturing and placing concrete is presented along with a directory of commercial testing laboratories in the United States.

ACI NEWS LETTER

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Annual report ....

1959--A Year of Change

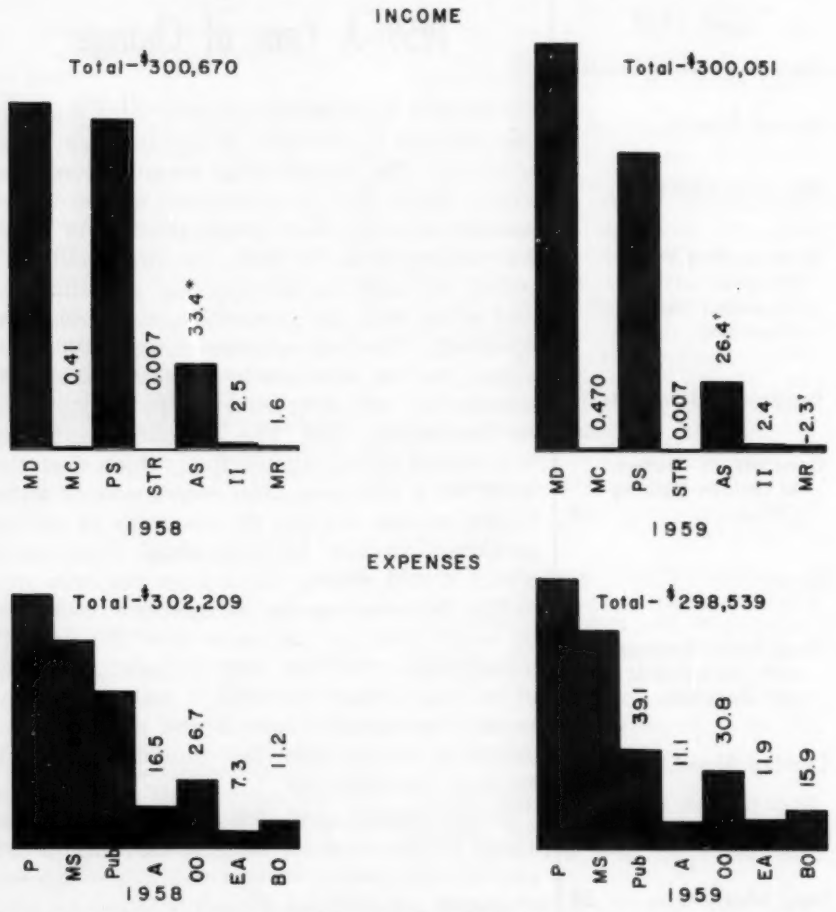
DURING 1959 MANY CHANGES were made in the methods of operation of the Institute headquarters. The membership records were converted to an IBM punched-card system which handles monthly dues billing, printing of labels for mailing of the JOURNAL, recording and compiling statistics on membership classification, and stores data for production of the biennial directory. The task of converting 10,000 individual records into punched cards took several months but was completed except for job titles by December, 1959. The punched cards are maintained by an outside firm which does the work on a fee basis. The conversion to automated records avoided the necessity of adding personnel in the Membership Department which would shortly have been required due to the increased number of member records to be maintained. At the same time the current membership staff has been relieved of many of the routine tasks entailed in maintaining up-to-date membership records and will have appreciably more time for promotional work amongst nonmembers.

At the beginning of 1959 a new member was added to the editorial staff so that one of the editors could devote his time to the development of special publications. Robert G. Wiedyke, who occupies this position, is currently dividing his time between the preparatory work on the *ACI 55-Year Index,* bibliographies prepared by technical committees, and other special editorial tasks. It is intended to publish the *ACI 55-Year*

Index during 1960 to fill a great need for an over-all index of ACI publications of which currently only those published since 1929 are indexed and even then the user must consult the *ACI 20-Year Index*, *"Supplemental 5-Year Index,"* and five individual annual indexes to search out references.

Fig. 1—Comparative income and expenses, 1958-59

Figures are given in thousands of dollars. 1958 total does not show discounts earned. Net operating income over expenses for 1958 was $693.42 and for 1959 was $1511.91



Code (income): MD—member dues; MC—member certificates; PS—publication sales; STR—sales tax received; AS—advertising sales; II—interest income; MR—miscellaneous receipts

Code (expenses): P—personnel; MS—member service; PUB—publications; A—advertising; OO—office operation; EA—external activities; BO—building operation

*Before deduction of 15 percent agency commissions
†After deduction of 15 percent agency commissions
‡Loss on redemption of bonds in investment account

The new index will start with the initial *Proceedings* volume published in 1905 and continue through the June, 1959, ACI JOURNAL (*Proceedings* V. 55).

A new method of publication of standards of the Institute was inaugurated with the July, 1959, ACI JOURNAL. Heretofore proposed standards or proposed revisions to standards have been published in the JOURNAL and then after ratification by the membership the standards have been republished in a later JOURNAL. To save this repetitive publication the Technical Activities Committee approved publication of the title and any amendments made after publication of the proposed standard. Coupons were made available by which members might order at no cost separate prints of the various new standards in special covers.

With reference to the JOURNAL, the Institute's major contact with the member, various changes included a modernization of the cover and a change in mailing date (so that the magazine reaches the member early in the month). A new printer is now handling the JOURNAL with greater speed and efficiency and at less cost than the previous printer. A readership survey was also instituted. To date helpful hints have been supplied to editorial and advertising staffs, and it is hoped that as data accumulates some trends in membership interests and reading habits will be indicated. The cooperation of members in filling out and returning these questionnaires has been greatly appreciated.

New employees joining the staff during 1959 were Kenneth D. Cummins, technical director; Richard Mehoke, assistant editor; Thomas Akas, advertising manager; and Mrs. Dorothy Weckerly and Mrs. Shirley Russell, dictaphone operators. Four employees, including Mrs. Mary Hurd, associate editor, and Charles Cousins, advertising manager, left the staff.

International relations

In 1959 the Institute marked a milestone by holding the regional meeting in Mexico City. This meeting was sponsored and put on by local members of the Institute in Mexico City and proved to be an excellent opportunity for exchange of views between Spanish and English speaking ACI members. Alberto Dovali Jaime, Universidad Nacional de Mexico; Adolfo Zeevaert, consulting engineer; and Leonardo Zeevaert, consulting engineer, were particularly active in making the meeting a success.

During the year a three-member delegation consisting of Raymond C. Reese, consulting engineer, Toledo; Eivind Hognestad, Portland Cement Association, Skokie, Ill.; and C. P. Siess,

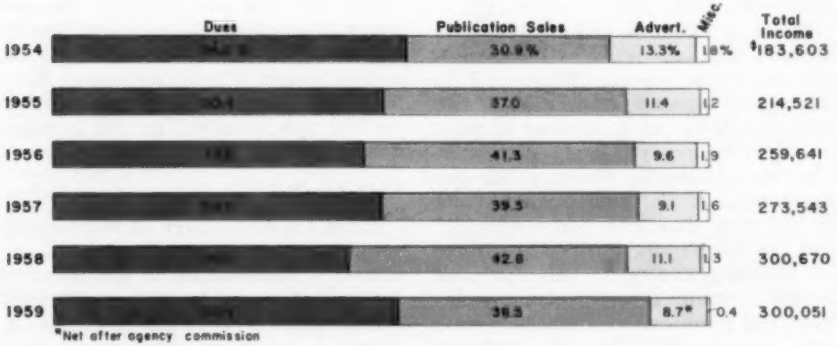


Fig. 2—Sources of income, 1954-59, in percent

TABLE 1—SUMMARY OF MEMBERSHIP GAINS AND LOSSES 1953-1959, INCLUSIVE

Year	Losses				Total applications	Net gain	Active at year end
	Deaths	Resignations	Nonpayment of dues	Total			
1953	28	171	395	594	974	380	6352
1954	23	159	367	549	896	347	6696
1955	26	159	396	581	1269	688	7387
1956	32	153	389	584	1641	1057	8444
1957	28	193	428	649	1428	779	9223
1958	29	219	592	840	1340	500	9723
1959	43	258	595	896	1283	387	10,110

University of Illinois, Urbana, was appointed to collaborate with the Comité Européen du Béton in the exchange of information and visits. These three members visited the 1959 meeting of the CEB in Vienna, Austria, and one member of the collaboration committee from the CEB, Inge Lyse, Norges Tekniske Hogskole, Trondheim, Norway, attended the 1960 ACI convention in New York last month. For the information of research workers and others in the concrete field, the collaboration committee has arranged for the translation and publication of the CEB reports resulting from the 1959 meeting in Vienna. In addition, arrangements are also under way for the preparation of summary papers by members of the CEB on work of their commissions to be considered for publication in the ACI JOURNAL. An earlier report of this kind on load factors was based on the work of a committee chairmanned by Eduardo Torroja and published in the November, 1958, ACI JOURNAL.

There is great current interest in Spanish translations of ACI standards and committee reports. "Pinturas Para Hormigon," Spanish translation of two ACI reports on the application of paint to concrete, prepared from ACI standard "Recommended Practice for the Application of Portland Cement Paint to Concrete Surfaces (ACI 616-49)" and the Committee 616 report "Guide for Painting Concrete," was approved by the committee on Spanish translations and published cooperatively with the Instituto del Cemento Portland Argentina, Buenos Aires. The committee consisting of Celso Carbonell, Panama, Adolfo Zeevaert, Mexico, and Edgarda Quintanilla, Peru, is now reviewing translations of the ACI Building Code and *Reinforced Concrete Design Handbook*. Interest has been expressed in translating the *Inspection Manual*.

Permission has recently been given for Norwegian and Italian translations of the *Concrete Primer*.

Finances

Over-all, the results of 1959 operations were comparable to those 1958 (Fig. 1). Total income was only slightly different, although as shown in Fig. 2, ACI member dues accounted for 52.4 percent of total income compared to 45 percent in 1958 whereas income from publication sales declined to 38.5 percent from 42.6 percent in the previous year. The net operating income over expenses for 1958 (after deducting discounts earned) was $693.42. The same figure for 1959 was $1511.91. The increase in member dues rate was largely responsible for the increase in total amount received from this source. Estimates for 1960 are that the percentage derived from dues will further increase during 1960.

Membership

Table 1 is a summary of membership activities over the past 7 years and indicates a continuation of the trend of the past 4 years in that while total membership is growing, the rate of growth is declining. Total applications and net gain during the year continued

to decrease while there was a small increase in the number of members lost. The most fruitful source of new members continues to be present members. The Membership Committee would welcome even greater activity on the part of individual members.

Publication sales

Publication sales in 1959 showed a softening influence with the net result of a decrease in publication sales of about 10 percent over the previous year. A number of factors account for this decline among them being the fact that ACI principal publications are one or more years beyond new editions and therefore are experiencing an expected gradual decline in sales. Table 2 illustrates this for the five principal ACI publications. Secondly, the number of bulk orders for reprints of JOURNAL papers declined during 1959 as compared to the previous year. A few large orders of this kind can change the publication sales figure materially over a year's time.

Recognizing the need for new publications, the Technical Activities Committee has authorized the development of a series of monographs on specialized subjects. Raymond C. Reese, ACI

TABLE 2—UNIT SALES OF ACI SPECIAL PUBLICATIONS

	1954	1955	1956	1957	1958	1959
Detailing Manual	5,864	6,031	7,430	11,472*	8,385	6,100
R/C Design Handbook	3,005	5,108*	5,265	4,181	3,765	4,165
Building Code	11,604	16,619	60,653*	20,859	27,775	26,725
Inspection Manual	2,385	6,619*	4,266	2,926*	4,318	4,167
Primer	1,377	797	1,032	1,840	4,599*	3,776

*New editions in these years.

TABLE 3—ACI MEMBERSHIP CLASSIFICATION, PERCENT*

	1953	1958	1960
Industrial classification (employer)			
Consulting engineer or engineering firm	30.1	35.1	32.9
Manufacturer or producer	20.0	25.1	21.6
Government	14.8	10.5	11.7
Educational institution	7.2	7.9	9.3
Architect	5.5	6.0	6.7
Contractor	11.0	4.7	7.4
Trade association	3.1	3.5	3.5
Laboratory	2.7	2.5	2.5
Utility	3.3	1.5	2.0
Library	2.1	0.1	0.1
Other	0.2	3.1	2.3
Occupation			
Engineer	61.7	65.8	60.6
Plant manager or supervisor	9.1	11.6	6.2
Miscellaneous	6.4	6.5	1.7
Teaching	6.4	6.4	6.5
Construction supervisor	11.9	4.5	5.7
Architect	4.7	3.8	4.1
Student	0.4	1.4	3.2
Owner			1.4
President			3.2
Vice-president			2.9
Manager			3.4
Regional or district manager			0.4
Administrative			0.5
Government administration			0.2

*Based on 5731 United States members.

vice-president, has been working closely with the ACI staff in developing possible authors for these booklets which are expected to range from probably 75 to 150 pages and will appear in a distinctive hard cover so as to become a permanent part of the user's library. So far there have been several commitments to prepare monographs and it is hoped that before the end of 1960 one or more of them can be in the near publication stage.

Earlier experience with the publication of the *ACI 20-Year Index* indicates that publication sales are increased by the availability of an up-to-date index of JOURNAL publications. Therefore the completion of the necessary editorial work on the *ACI 55-Year Index* has a high priority at ACI headquarters and it is planned to publish the book during 1960 if at all possible. Due to the cost of publication it will not be possible to make free distribution of this book as was done with the earlier indexes. However, it is planned to make a prepublication offer to ACI members at as low a price as possible to encourage wide distribution.

Chapter activities

The present three chapters in southern California, northern California, and Oklahoma have been active during the year but aside from a group in Detroit progress has lagged in organizing other new chapters. There are several groups throughout the country which have expressed interest in chapter organization.

Membership classification

Results of a recent tabulation of member classifications derived from the IBM records are shown in Table 3 along with similar data derived from earlier surveys.

Ellsberg honored

Harry Ellsberg, chief structural engineer, Giffels and Rossetti, Detroit, recently received the 1959 Concrete Achievement Award sponsored by Huron Portland Cement Co. on behalf of the Concrete Improvement Board of Metropolitan Detroit. The award, in the form of an engraved plaque, was presented to Mr. Ellsberg at the February meeting of CIB by Peter Antonich, Huron Portland Cement technical services department engineer.

Peter Antonich (left) presents 1959 Concrete Achievement Award to Harry Ellsberg (right)

Mr. Ellsberg was cited for his efforts in promoting specifications and quality concrete in various projects, including such prominent Detroit structures as Cobo Hall and the new U. S. Post Office building.

Mr. Ellsberg is chairman of ACI Committee 622, Formwork for Concrete.

McHenry to represent ACI at international meeting

ACI Past President Douglas McHenry, vice-president in charge of research and development, Portland Cement Association Research and Development Laboratories, Skokie, Ill., will represent the American Concrete Institute at the Sixth Congress of the International Association for Bridge and Structural Engineering in Stockholm, Sweden, June 27-July 1, 1960.

Lerch and Scholer Named ACI Honorary Members

HONORARY MEMBERSHIP IN THE AMERICAN CONCRETE INSTITUTE was conferred on two eminent members in recognition of their outstanding contributions in the field of concrete and in the work of the Institute at the Award's Luncheon, March 16, during the 56th annual convention in New York.

Joining the ranks of ACI honorary members are William Lerch, cement and concrete consultant, and formerly assistant to the vice-president for research and development of the Portland Cement Association, Skokie, Ill., and Charles H. Scholer, consultant, formerly head of the Department of Applied Mechanics at Kansas State College, Manhattan, Kan. This makes a total of 31 honorary memberships which have been granted in ACI history.

William Lerch

William Lerch received a BS from Beloit College in 1918 and a MS in chemistry from the University of Wisconsin in 1922, and has been a member of the research staff of the Portland Cement Association since 1923. He was on the staff of the Portland Cement Association Fellowship at the National Bureau of Standards from 1924 to 1940 and at the PCA Research Laboratories since 1940 where he has been engaged in studies of the chemistry of cement and concrete.

Mr. Lerch has published many noteworthy papers on the chemistry of cement and concrete and on air-entrained concrete. In 1947 and again in 1950 he received the Sanford E. Thompson Award for the most meritorious paper on cement and concrete presented at the annual meetings of the American Society for Testing Materials.

The record of published papers is only a partial record of Mr. Lerch's contributions to the science and technology of cement and concrete. His authoritative knowledge of the chemistry of cement and concrete, together with his knack of reducing scientific information to practical and useful terms, has been recognized throughout the industry. That knack has played an important role in the development of sound specifications for portland cement, concrete, and concrete products.

Mr. Lerch, an Institute member since 1945, is an active member of numerous committees of the American Concrete Institute, American Society for Testing Materials, and the Highway Research Board. He is also a member of the Concrete Committee of the International Commission on Large Dams. He is currently a member of ACI Committee 624, Portland Cement Plaster.

Charles H. Scholer

Charles H. Scholer, a past president of the American Concrete Institute, has long been active in Institute affairs, both in technical and administrative committees. He is currently chairman of ACI Committee 714, Concrete Bins and Silos, and a member of Committee 115, Research; Committee 201, Durability of Concrete in Service; Committee 209, Volume Changes and Plastic Flow in Concrete; Committee 215, Fatigue of Concrete; and Committee 611, Inspection of Concrete.

Professor Scholer was graduated from Kansas State College with a BS in civil

engineering in 1914. His early professional experience was received in New Mexico on General Land Office surveys and in Kansas on railroad surveys and highway bridge design and construction. Professor Scholer was head of the Department of Applied Mechanics at Kansas State College from 1923 to 1956, when he retired to enter private consulting work. Professor Scholer was head of the Road Materials Laboratory for the Kansas State Experiment Station from 1919 to 1939. He took leave of absence from Kansas State College in 1939-40 to take charge of investigational work in New York and Pennslyvania for the Portland Cement Association.

Eminent in the field of research in engineering materials, especially concrete, Professor Scholer has written many technical papers and discussions dealing with concrete, and he was one of the first to discover the benefits of entrained air in improving the durability of concrete. Many of his papers have been published by ACI, American Society for Testing Materials, Highway Research Board, and the Kansas Experiment Station. In 1952 Professor Scholer was awarded the ACI Wason Medal for Research for work reported in "Use of Chicago Fly Ash in Reducing Cement - Aggregate Reaction," which he coauthored with Gerald M. Smith.

He has been active in highway work throughout his professional career and was chairman of the Executive Committee of the Highway Research Board during 1958-59. He has been honored by election to Sigma Tau, Sigma Xi, and Phi Kappa Phi.

American Cement announces acquisition of two firms

American Cement Corp., Philadelphia, has announced the acquisition of M. F. Hickey Co., Inc., New York, and Graham Brothers, Inc., Los Angeles. Both companies have been active in the ready-mixed concrete business for more than 40 years. Graham Brothers, Inc., is also a large producer of sand and gravel in the Los Angeles area.

The two companies will be operated as subsidiaries of American under the policies and procedures which they have followed in the past. Lawrence F. Hickey will continue as president of M. F. Hickel Co., Inc., and Paul C. Graham and Russell C. Graham will continue as chairman of the board and president, respectively, of Graham Brothers, Inc.

BRI schedules spring conference

The Building Research Institute will conduct its spring meeting at the Statler-Hilton Hotel in New York, April 5-7.

The 3-day program will present a session on insulated masonry cavity walls, discussing new methods of design for such walls with respect to structural thermal characteristics, as well as new developments in anchorage and reinforcement, and in mortars for cavity walls. The session will spotlight the tremendous progress made in this field in the past few years, citing pertinent factors affecting design and construction in today's masonry buildings.

Other program topics will include: adhesives in building, surface preparation and field application of paints and coatings, roundup of research projects on building, and a series of proposals for new building research by organizations throughout the country.

Nelson joins Sika staff

E. Harold Nelson has joined the Boston district office of Sika Chemical Corp. as a sales engineer. He will cover the Connecticut-Massachusetts area. Prior to joining Sika, Mr. Nelson was manager of a materials testing laboratory in New Haven.

Tests on Flat Plate Structure of Expanded Shale Concrete

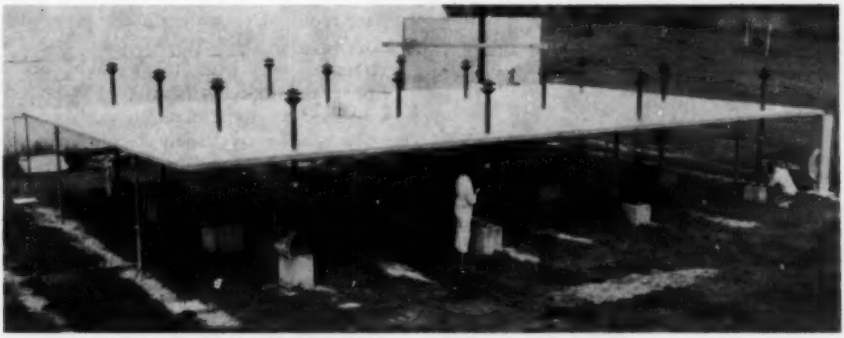
THE DIVISION OF BUILDING RESEARCH, Commonwealth Scientific and Industrial Research Organization, Australia, has recently begun a study of all aspects of the behavior of a lightweight flat plate structure.

The concrete was made with expanded shale aggregate. Standing on 16 steel columns, 5 ft high, the slab is 3½ in. thick and 48 x 27 ft. It spans three bays in each direction, the spans being 12 ft in one direction with cantilevers of 6 ft at each end, and 9 ft in the other direction.

Measurements have already been taken of the deformation of the formwork and the structure itself during the placing of the concrete and after stripping. In the next phase the deformations due to concrete shrinkage and foundation settlement will be observed, and when these appear to have ceased the vertical design live load will be applied in various combinations of panel loading. Subsequently it is proposed to examine the lateral stiffness and stability of the structure by loading it horizontally to simulate wind load. It is hoped to be able to introduce various types of partition wall at this stage to study their influence on the lateral rigidity. After dynamic testing, the structure will be loaded to destruction.

This project has been made possible by the cooperation of Messrs. Hansen and Yunken, Ready Mixed Concrete; Reids Lightweight Aggregate; and many other firms associated with the building industry. Although not made specifically for this project, it has also been helped greatly by an annual grant from the Cement and Concrete Association.

The research is being done by the staff of the Mechanics and Physics Laboratory of the Division, under the supervision of F. A. Blakey. Strain measuring arrangements are the responsibility of F. D. Beresford and R. E. Lewis; structural design was done by R. K. Lewis and the concrete mix proportioning and control tests were the responsibility of E. N. Mattison. Cooperation has also been received from the staff of the Civil Engineering Department, University of Melbourne, under Prof. A. J. Francis, notably with regard to the design of the footings and measurements of soil pressures.



Flat plate test slab built by Division of Building Research, CSIRO, Australia

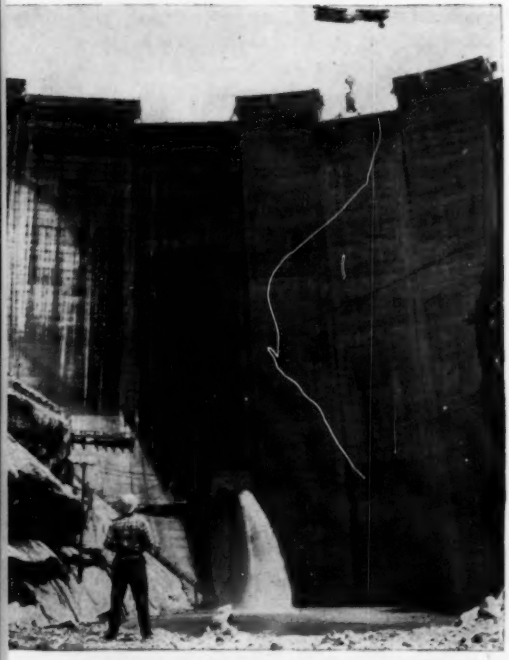
CONCRETE PERFORMANCE REPORT:

POZZOLITH concrete used in the Tri-Dam Project to meet full range of engineering requirements for all types of concrete specified . . . saves $86,000 in costs of concrete alone

The Tri-Dam Project in south-central California is one of the most interesting hydraulic programs undertaken in recent years. Each of the three structures represents a different basic type of dam being constructed in North America today.

Donnells Dam is a graceful concrete arch. Tulloch Dam is a concrete gravity structure and Beardsley Dam a rolled earth fill dam with a concrete spillway.

TRI-DAM



DONNELLS DAM rises 480 feet above foundation. This project included construction of a 7-mile long concrete-lined tunnel, penstock and powerhouse.

Shortly after the project began, laboratory and field tests were made to determine the quality and economy of POZZOLITH concrete—using cement and aggregates already in use on the project.

Results showed that the POZZOLITH Retarder mix would lower the rate of temperature rise in the mass concrete . . . reduce total heat evolved . . . provide other basic improvements in quality . . . and produce substantial savings in cost of concrete. Net savings were computed after allowing for the cost of additional aggregate required to maintain the same yield.

A total of over 515,000 cubic yards of concrete were used for tunnels, powerhouses and the dams themselves. POZZOLITH was used in 499,715 cubic yards of concrete to effectively aid in placing operations in all situations encountered. Strength requirements were met with substantial reduction in cost of concrete.

The net savings averaged $0.172 per cubic yard—a total of $86,000.

Concrete work at Tri-Dam extended through all seasons with temperatures ranging from 110°F to below freezing. Maximum aggregate sizes of the mixes ranged from ¼" to 6" and design strengths ranged from 2,000 to 3,000 psi at 28 days.

TULLOCH DAM stretches nearly ½ of a mile across the Stanislaus River. Here POZZOLITH Retarder proved particularly beneficial in mass concrete during summer months when the temperature soared to 110°F.

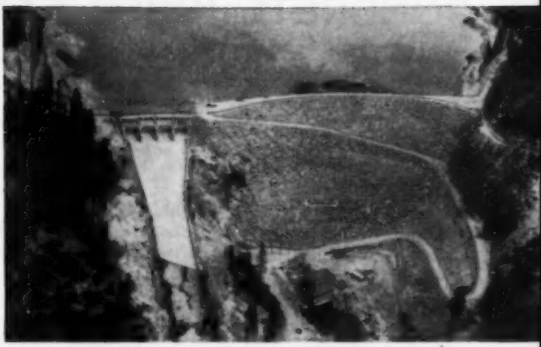
TRI-DAM FACILITY is jointly owned and operated by the Oakdale and the South San Joaquin Irrigation Districts, California. Design Engineers: George T. Goodall Co. & International Engineering Co., Inc. • Project Engineers: Tudor-Goodenough Engineers • Contractors: Donnells Dam and Beardsley Dam—Tri-Dam Contractors (a joint venture by Morrison-Knudsen Co., Peter Kiewit Son's Co., Macco Corp., and Stolte, Inc.); Tulloch Dam—The Arundel Corp. and L. E. Dixon Co.

PROJECT

Throughout the project, Master Builders field men assisted in solving on-the-job concrete problems . . . adding their experience and know-how to that of Tri-Dam Project engineers, contractors and concrete suppliers.

The local Master Builders field man will welcome discussing *your* requirements. Call him in to demonstrate how concrete produced with POZZOLITH is superior in quality, performance and economy to plain concrete or concrete made with any other admixture.

Write for your free copy of the detailed "Tri-Dam Concrete Performance Report".



BEARDSLEY DAM—an earth fill dam with concrete spillway. The structure is 1,000 ft. long and 280 ft. high.

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SPRING CHILL SLOWING DOWN YOUR CONCRETE JOBS? STAY ON SCHEDULE WITH COLUMBIA CALCIUM CHLORIDE

Warm spring days are almost here. But don't be caught off guard. There are still plenty of days—and nights—ahead when temperatures will skid below 70°. And you're still faced with the problem of keeping jobs on schedule in spite of the lag in concrete set caused by these low temperatures. You can keep cold weather jobs *moving* by adding Columbia Calcium Chloride at the rate of 2% by weight of cement to your mix. Columbia Calcium Chloride gives you these time-and-profit-saving benefits:

Higher Early Strengths—At 40°F, you get 3-day strength in 1 day, 7-day strength in 3½ days. There's no cold weather lag in strength gain; your job stays on schedule.

Faster Initial Set—Under normal conditions, Columbia Calcium Chloride cuts initial set time from 3 hours to 1 hour. At lower temperatures, the effects are even more pronounced. You get finishers on and off the job faster, avoid costly overtime.

Early Form Removal—Rapid strength gain permits removal and re-use of forms in about half the normal time.

Are you getting these Columbia Calcium Chloride cold weather benefits on your concrete jobs? If not, better analyze your batching procedure or contact your ready mix supplier today. Specify Columbia Calcium Chloride.

For more information on Columbia Calcium Chloride, contact our nearest District Sales Office or write our Pittsburgh address. *You'll like doing business with Columbia-Southern.*

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Positions and Projects

1960 Regional Meeting to be held in Tucson

The ACI 13th Regional Meeting will be held at the Pioneer Hotel, Tucson, Ariz., Oct. 31 and Nov. 1-2, 1960.

Gene M. Nordby, head, civil engineering department, University of Arizona, is general chairman of the meeting with Andrew Ross, vice-chairman and Joseph Toth, treasurer, both of the University of Arizona. Edward Mangotich, Portland Cement Association, is on the executive planning committee.

Billy J. Shell, San Xavier Rock and Sand Co., is technical program chairman. The tentative program features four technical sessions covering the areas of buildings, highway structures and pavement, construction, and research and theory.

Other key committee posts announced by Professor Nordby include: Lee Lawrence, civil engineer, finance chairman; Edward Mangotich, PCA, in charge of exhibits; Gene Anderson, civil engineer, publicity chairman; and Andrew Marum, consulting engineer, membership chairman.

Maurice LeGaard is in charge of the ladies' program; James Kreigh, educational contacts; and K. K. Kienow, registration. The latter three members of the local planning committee are all affiliated with the University of Arizona.

Northern California Chapter holds first annual meeting

The ACI Northern California Chapter held its first annual meeting on March 2 in San Francisco. Organized in 1958, the chapter now has 66 members: 1 Honorary; 57 Individual; 3 Corporation; 2 Contributing; and 3 Junior.

During the past year the chapter has held four meetings with an average attendance of 63 per meeting. The chapter has established its professional position with other similar organizations in the northern California area; established bylaws; and cosponsored the "Practical Concrete Conference" with the University of California.

Newly elected chapter officers installed at the meeting were: Harry E. Thomas, materials testing engineer, Pacific Gas and Electric Co.; Emmeryville, president; Milos Polivka, professor of civil engineering, University of California, Berkeley, vice - president; and Rolf T. Retz, construction specifier, standards section, California State Division of Architecture, Sacramento, and D. K. Woodin, senior construction inspector, East Bay Municipal Utility District, Oakland, directors for 3-year terms.

S. D. Burks, Dewey and Almy Chemical Co., San Leandro, is outgoing president. W. E. Moulton, testing engineer, Pacific Cement & Aggregates, Inc., San Francisco, will continue as secretary-treasurer of the chapter.

The principal speaker at the annual meeting was Raymond E. Davis, consulting engineer and director emeritus, Engineering Materials Laboratory, University of California, who spoke on "Four Decades with Concrete."

ACI Committee 325 records vote of thanks to Finney

On the resignation of E. A. Finney, director, Research Laboratory, Michigan State Highway Department, East Lansing, as chairman of ACI Committee 325, Structural Design of Concrete Pavements for Highways and Airports, the committee, meeting Jan. 10, 1960, in Washington, D.C., unanimously adopted a resolution to record its appreciation as follows:

"Chairman E. A. Finney announced his resignation and the appointment of Henry Aaron as his replacement. Upon installation of Chairman Aaron, the committee resolved that an expression

of appreciation to Mr. Finney be recorded for his contributions to the advancement of concrete pavement design through his work on this committee since its origin in 1948. His work as chairman since 1952 resulted in collection, analysis, and evaluation of all available theoretical, research, and performance data by the committee, published in 1956 as four informative reports which were then combined under Mr. Finney's direction into a comprehensive standard for the design of concrete pavement for highways and airports. This standard, published in 1958, and adopted by the American Concrete Institute as an ACI Standard, has been generally accepted by highway and airport engineers and public agencies as authoritative. In 1958 Mr. Finney reorganized the committee and established as a new objective for its work the development of design standards for the three major new developments in the field of concrete pavement — continuous reinforcement, overlays, and prestressed concrete. He leaves the committee and its new chairman well underway toward the new objective, preliminary informational reports on all phases of the new work having been published, and a functioning system of collecting new data as it becomes available in operation. This outstanding record of accomplishment as chairman of an ACI technical committee is a source of as much pride to the committee as it must be to the retiring chairman."

Long active in executive and technical committee work, Mr. Finney is currently a member of the ACI Board of Direction, a member of the Technical Activities Committee and Committee 116, Nomenclature, and ACI representative to the Highway Research Board.

Henry Aaron, Wire Reinforcement Institute, Washington, D.C., assumes the chairmanship of the committee well informed of its activities since he has acted as secretary of Committee 325 since its organization in 1948.

ACI cooperates in USU concrete conference

The 2nd Concrete Conference of Utah State University, Logan, was conducted February 25 with close to 200 engineers, contractors, suppliers, and students in attendance.

Eight papers were presented at two technical sessions. Kenneth D. Cummins, ACI technical director, opened the morning technical session with a discussion of technical progress in concrete. Chris Pickett, Portland Cement Association, Salt Lake City, spoke on quality concrete in flatwork; William A. Cordon, Utah State University, covered the influence of admixtures on quality of concrete; and Allan W. Flandro, Utah Sand and Gravel Corp., Salt Lake City, concluded the first technical session with his discussion of quality control through ready-mixed concrete supply.

J. R. Walton, U. S. Bureau of Reclamation, Dutch John, Utah, opened the afternoon technical session with a paper on construction at Flaming Gorge Dam; Paul Buehner of Otto Buehner Co., Salt Lake City, discussed decorative use of concrete; Derwin Merrill, Ideal Cement Co., Fellowship at USU, spoke on concrete durability. Walter C. Oram, Portland Cement Association, Salt Lake City, rounded out the program with a discussion of new shapes in concrete.

The conference was conducted by the Engineering Experiment Station and Civil Engineering Department at USU in cooperation with ACI and PCA.

Nicholson addresses Michigan area group

James A. Nicholson, president of Toledo Plaster and Supply Co., Toledo, Ohio, was guest speaker at the February meeting of ACI members and guests from the Detroit metropolitan area.

Mr. Nicholson, a past president of the Ohio Ready-Mixed Concrete As-

sociation and a director of the National Ready-Mixed Concrete Association, spoke on the subject of ready-mixed concrete. He touched briefly on all contributing factors such as materials, workmanship, and inspection, stressing the point that there must be complete cooperation between architect, engineer, supplier, contractor, and inspector. He made suggestions for specifications and means of controlling the quality of plastic and hardened concrete.

The members present signed a petition asking for formal establishment of a Michigan chapter of the American Concrete Institute. The petition was submitted to the Board of Direction at the time of the annual convention in New York City.

Southern Lightweight adopts new firm name

Announcement has been made by Southern Lightweight Aggregate Corp., Richmond, Va., that the firm name has been changed to Solite Corp.

Iowa State conducts annual Better Concrete Conference

The 11th annual Better Concrete Conference was held March 3-4 at Iowa State University, Ames. Herbert J. Gilkey, former head of Theoretical and Applied Mechanics at the university, arranged the program which presented latest theories, methods, and applications to ensure better concrete.

At the opening session Gerald Bogan, Iowa Good Roads Association, Des Moines, spoke on the potential pitfalls in the interstate program and George R. Bathe, Ready Mixed Concrete Co., Omaha, discussed the problems, progress, and advantages of ready-mixed concrete for highway pavements.

Kenneth D. Cummins, ACI technical director, spoke at the luncheon meeting on March 3, as well as S. J. Chamberlin, Iowa State University, who presented a report on the ACI Mexico City regional meeting.

Among the other speakers and their topics were: H. A. Welton of W. A.

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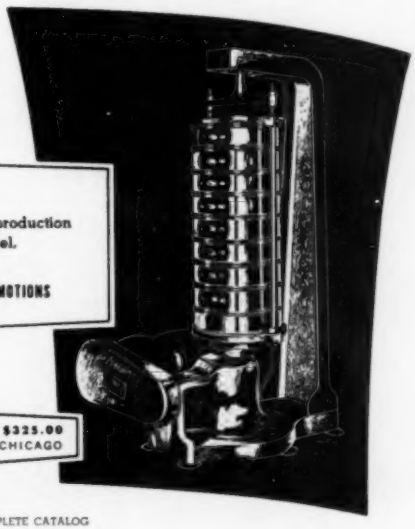

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Klinger, Inc., Sioux City, who discussed current refinements in forming and finishing pavement and other concrete; and A. M. Hensing, Iowa State Highway Commission, Ames, spoke on current procedures in cold weather placement of concrete.

Three speakers participated in a session devoted to admixtures in concrete: Raymond J. Schutz, Sika Chemical Corp., Passaic., N.J., Fred F. Bartel, Tews Lime and Concrete Co., Milwaukee, and Thomas J. Reading, Missouri River Division, Corps of Engineers, Omaha.

On Thursday evening, March 3, a forum on problems of testing and rejections was held with Joseph E. Borg, Brooks-Borg, architects-engineers, Des Moines, speaking from the standpoint of the architect; W. H. Campen, Omaha Testing Laboratory, Omaha, speaking from the standpoint of the testing laboratory; and Thomas J. Reading speaking from the standpoint of the client.

PINTURAS PARA HORMIGON

Spanish translation of two ACI reports on the application of paint to concrete. Prepared from ACI Standard 616-49, **"The Application of Portland Cement Paint to Concrete Surfaces,"** and the Committee 616 report on **"Guide for Painting Concrete."***

●

$1 per copy

●

ACI PUBLICATIONS DEPARTMENT

*Both reports are available as separate booklets in English.

The program on March 4 presented discussions by Carl Ekberg, Iowa State University, on prestressing, and current researches on concrete and concrete materials by Hubert Woods, Portland Cement Association, Skokie.

One session was devoted to thin shell structures, adaptations and problems, with Ralph E. Spears, PCA, Kansas City, discussing forming and building, and Harold J. Jobse, PCA, Des Moines, adding more data on thin shell structures.

Rounding out the program, conference chairman Gilkey spoke on "Concrete's Ignored Constituent"; Henry Banker, PCA, Chicago, spoke on architectural concrete—specials forms and finishing; and R. E. Brown, Shell Chemical Co., New York, discussed epoxies. Howard Macy, Macy Brothers, Inc., Lynnville, Iowa, presented a convention report on the annual meeting of the National Ready Mixed Concrete Association held in Chicago.

The conference was sponsored by the Iowa State University Engineering Extension in cooperation with ACI, American Institute of Architects (Iowa), American Society of Civil Engineers (Iowa), Associated General Contractors of Iowa, Iowa Engineering Society, Iowa Highway Commission, Iowa Ready-Mixed Concrete Association, Master Builders of Iowa, and Portland Cement Association.

PCA creates new Paving Bureau

The Portland Cement Association has announced the merger of its Highway and Municipal and Soil-Cement Bureaus into a single Paving Bureau at its general office in Chicago.

Gordon K. Ray, former manager of the Highways and Municipal Bureau has been named manager of the new Paving Bureau, which will be responsible for providing engineering service and developing technical and promotional information on both concrete and soil-cement pavement.

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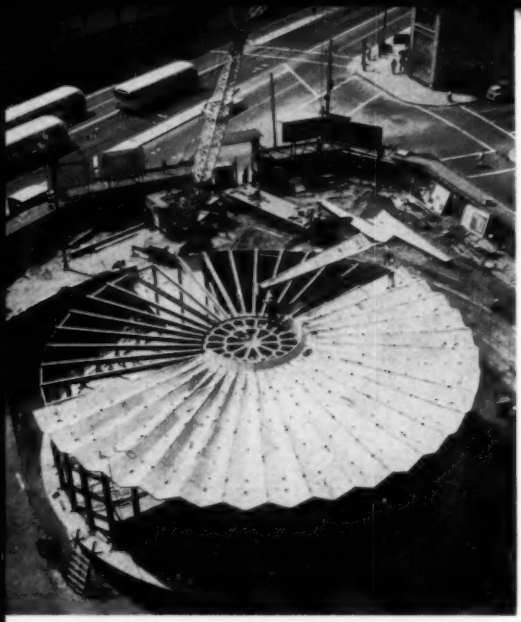


Concrete Is Feature of Unique Banking Office

AMERICAN TRUST CO.'s round, glass-walled, copper-roofed banking office in San Francisco makes extensive and special use of concrete in its foundation, below grade structure, and roof. New in concept and departing from traditional bank architecture, the bank is a circle 70 ft in diameter with walls of clear plate glass and a concrete "folded plate" roof sheathed with copper.

High capacity pretensioned piles 36 ft long and 12 in. in diameter comprise the foundation. They are equally spaced at 13½-ft intervals on a 70-ft diameter circle and grouped under the bank's vault area. High strength concrete, 5000 to 6000 psi, gives the piles an unusually high bearing value of 65 tons per pile.

The below grade structure consists of a 9 in. thick basement floor slab, increased to 18 in. under the bank vault.

Rising from the basement floor slab are 12-in. walls which support a 9½ in. thick slab ground floor.

Precast folded plate roof

It is in the roof structure that precast concrete is used in a dramatic and novel way.

To provide the bank with an unbroken interior, the roof structure rests on 40 slender steel columns set on the perimeter of the 70-ft diameter concrete slab. Joining with the 40 vertical supporting columns are an equal number of steel beams that radiate from a central hub like the spokes of a wheel. The hub, itself, is in the form of a steel Gothic Rose.

On top of the roof beams are placed precast lightweight concrete shell elements that fan out from the roof's center in a continuous and regular folded or pleated manner. Precast units are bolted to steel beams and welded together along channels cast in concrete.

The concrete elements do not participate directly in the structural action except to give torsional and bending stiffness. Their main function is an aesthetic one—to establish the design of the roof which is the bank's most distinctive feature.

The roof has been clad with sheet copper which will weather to a characteristic green. This special effect was provided solely for the benefit of tenants of surrounding office buildings.

Part of the Crown Zellerbach Plaza, the building was designed by Skidmore, Owings & Merrill, San Francisco; general contractors were Haas & Haynie, also of San Francisco.

Parme to head new advanced engineering group of PCA

The Portland Cement Association has announced the formation of an Advanced Engineering group at its general office in Chicago, headed by Alfred L. Parme, nationally recognized authority on structural engineering.

G. Donald Kennedy, president of PCA, described the new group as a "highly specialized unit, bringing together unusual engineering talent for the development of basic engineering data." Its purpose will be to apply the most advanced engineering, mathematical, and physical principles, and the most modern test data, to achieve even more efficient use of concrete in all of its many applications.

Methods of design of large dams, building frames, and concrete shell roofs were cited as some areas in which advanced work will be undertaken by the new group. In addition to highly complex engineering studies, significant design and construction contributions from foreign and other sources will be reviewed, specialized computer programs originated, and advancements in various fields of concrete use analyzed as to their most effective application to other areas.

Before joining PCA as a structural engineer in 1940, Mr. Parme was with Ebasco Services, Inc., engineering firm of New York City, and with the U. S. Corps of Engineers in Binghamton, N. Y.

Long active in ACI committee work, Mr. Parme is currently chairman of ACI-ASCE Committee 328, Limit Design; secretary of Committee 334, Concrete Shell Structures; and a member of ACI Committee 314, Rigid Frames for Buildings and Bridges; Committee 340, Ultimate Strength Design Handbook; and ACI-ASCE 326, Shear and Diagonal Tension.

In 1953 he was awarded the Fuertes Graduate Medal by Cornell University for his work on a concrete shell roof design manual and this year received the Moisseiff Medal awarded by the American Society of Civil Engineers for his contributions to design in this field. He is the author of numerous technical articles and publications.

Mr. Parme's former position as manager of the Structural and Railways Bureau will be filled by Walter E. Kunze, formerly assistant manager of the bureau, and most recently manager of personnel training. Prior to joining PCA in 1952, he was a structural designer with the consulting engineering firms of Metcalf and Eddy in Boston, and Toltz, King, and Day of St. Paul, Minn.

Detroit CIB elects officers

The Concrete Improvement Board of Metropolitan Detroit has elected W. G. Irmscher, Peerless Cement Co., chairman for 1960. John Tucker, Ready Mix Concrete, Inc., was elected secretary.

Directors for 1960 include Larry Clark, American Aggregates Corp.; J. W. Winkworth, J-W Materials, Inc.; Robert Wilde, American Concrete Institute; Carl Dambrun, Jr., Pittsburgh Testing Laboratory; Eugene McCracken, Barton-Malow Co.; Arthur Moy, Detroit Department of Buildings and Safety Engineering; Robert Belucci, Giffels and Rossetti; and William Harris, Harris Concrete and Supply Co.

International Association for Shell Structures organized

The aim of continuing development of design and construction techniques of shell structures has encouraged the formation of the International Association for Shell Structures. The group will organize meetings and congresses for the interchange of ideas and their dissemination through appropriate journals.

IASS activities will be directed by an executive council, a third of which will be elected every 2 years. To ensure the international character of the association, only two members of the

same country may be elected simultaneously.

The present executive council is as follows: E. Torroja (Spain), president; A. L. Parme (USA) and W. Olszak (Poland), vice-presidents; F. Levi (Italy), treasurer; A. Aas-Jacobsen (Norway); A. L. L. Baker (Great Britain); N. Esquillan (France); A. M. Haas (Holland); R. S. Jenkins (Great Britain); K. W. Johansen (Denmark); O. D. Oniashvilli (USSR); A. Paduart (Belgium); H. Rühle (German Democratic Republic); W. Zerna (Federal Republic of Germany); and F. del Pozo (Spain), secretary.

Details regarding membership in IASS are available from the Secretariat of the International Association for Shell Structures, Alfonso XII, 3, Madrid (7), Spain.

Precast concrete industry plans international congress

The 3rd International Congress of the Precast Concrete Industry is scheduled for June 16-22 at Sankt Erikshallen, Stockholm, Sweden.

The congress is being organized by the Bureau International du Béton Manufacturé (BIBM) in Brussels in cooperation with the Swedish precast concrete industry's branch association, Cementvarufabrikernas Riksförbund (CR) in Stockholm.

The meeting's technical-scientific program comprises general reports, papers, films, and discussions on a number of subjects concerning the precast concrete industry. All papers and contributions to the general discussions during the congress will be simultaneously interpreted to and from the official languages of the congress, i.e., English, French, German, and Scandinavian.

An international exhibition, the Precast Concrete Industry's Fair, BIM 60, will be arranged on the congress premises. A number of study tours have been scheduled prior to and following the congress.

AIA honors Yamasaki

Minoru Yamasaki has been advanced to Fellowship in the American Institute of Architects. He was advanced to this highest type of membership in the national body for his "notable contribution in design."

Mr. Yamasaki, principal in the firm of Minoru Yamasaki and Associates, Birmingham, Mich., has won numerous awards in the past few years. He is now recognized as one of America's most imaginative architects.

Three Detroit area buildings recently designed by the Yamasaki firm are the American Concrete Institute headquarters, the McGregor Memorial Conference Center, and the Reynolds Metal Co. sales office.

Columbia Cement names Cobb works manager

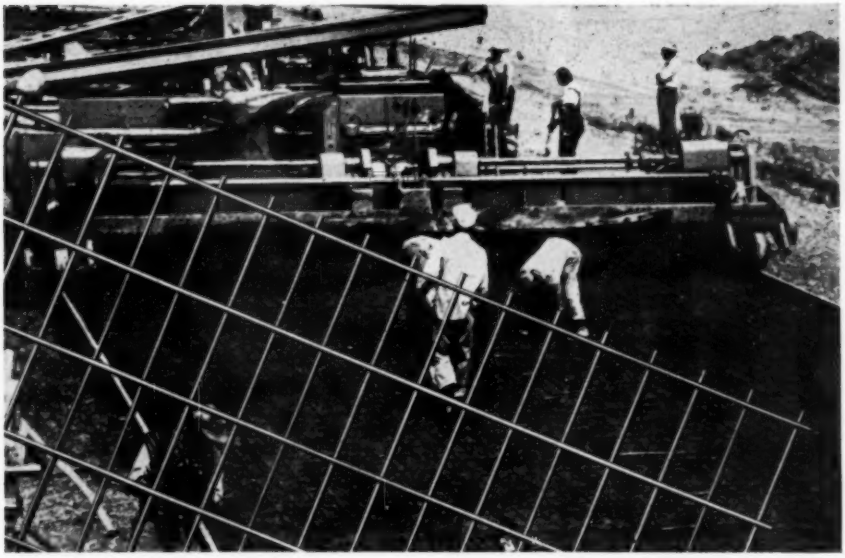
George L. Cobb was recently appointed works manager for the Zanesville, Ohio, plant of Columbia Cement Corp. He was formerly chief engineer at Columbia-Southern's Natrium, W. Va., chemical plant.

Mr. Cobb succeeds the late Walter K. Farst who had served as vice-president in charge of operations and general manager of Columbia Cement Corp., a wholly-owned subsidiary of Columbia-Southern Chemical Corp., Pittsburgh.

American-Marietta acquires Beu facilities

The quarries, stone crushing facilities, and sand and gravel plant of Beu and Sons Co. and Beu Limestone Co. of Grundy Center, Iowa, have been purchased by American-Marietta Co.

Fred E. Bellamy, president of Concrete Materials and Construction Division, American-Marietta Co. of Cedar Rapids, Iowa, announced that the former Beu companies will become a part of the division, and the name will be changed accordingly. Present principals will remain in charge and production and supervisory personnel will be retained.



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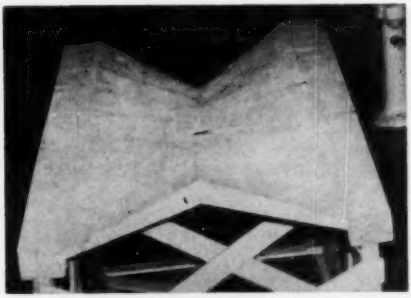

New application of hyperbolic paraboloids is being investigated at Case Institute of Technology, Cleveland. Model is 6 x 3 ft in plan. Forward cantilever is approximately 3 ft; edge ribs are 5 x 3 in.; forward and end ribs are 2 x 2 in.; 1/8 in. wire, weld splattered, is used as main reinforcement. Shell is 1/2 in. thick and ultimate load was 175 psf. Data are being correlated by George Griffen as part of his master's program, under the supervision of John B. Scalzi, associate professor of structural engineering.

Experts recommend conditions to stimulate research

Scientific and technological advance could be speeded if this country's research and development were conducted under conditions which would stimulate greater originality according to 51 of the nation's top scientists, researchers, and educators. The group conferred for 2 days last December at Worcester Polytechnic Institute under auspices of the National Science Foundation in cooperation with 15 leading scientific and engineering societies.

It was their contention that research people too easily become preoccupied with goals of relatively small dimensions which promise little in significant discovery and that progress will be influenced far more by those who can strike out with vigor and vitality for breakthroughs on frontiers of science.

They felt that the young researcher is steered in the direction of conservatism by his education, research support, and professional societies as well as social and cultural environment. More rapid and efficient progress, they felt, might reasonably be expected if greater encouragement were to be given for more young people to leapfrog for the distant goals. To this end, a conference resolutions committee recommended that colleges and universities:

(1) Develop educational programs which require the student to exercise a high degree of originality and independence of thought. The student should be challenged with creative experiences throughout his entire educational experience.

(2) Bring talented youth into stimulative personal association with leading scientists and engineers.

(3) Doctoral research should encourage more venturesome attitudes. A graduate student should not necessarily be penalized by failure to complete distant objectives.

(4) Develop institutional policies which provide an encouraging environment for venturesome research. This starts with faculty members who themselves are creative.

(5) Develop closer liaison between college, industrial, and governmental research organizations.

(6) Encourage undergraduate and graduate students who have novel, creative ideas to pursue the development of these ideas and help them to obtain financial support.

The group made the following recommendations to scientific and engineering societies:

(1) Establish more effective practices which will increase the attendance and participation of talented young members at meetings of scientific and engineering societies.

(2) Encourage the presentation and publication of philosophical papers which look to the future of science and technology.

(3) Develop comprehensive programs for digesting research knowledge.

(4) Establish society meetings to develop more effective interchange of ideas between scientists and engineers in research areas of broad mutual interest.

(5) Establish free forums at engineering society conventions where any member may make a short presentation of his creative work.

(6) Actively promote and encourage financial support for research.

(7) Foster among society members a recognition of the contribution which they can make by stimulating at an early age the creative development of youth.

The report urged the scientific and engineering societies to take the initiative in bringing together leaders in education, industry, and government to study the problems of large-scale research. The committee recommended that such studies be approached, not in the framework of preconceived ideas and the preservation of tradition, but rather with a fresh, new, and objective outlook.

NRMCA-NSGA fund to aid research fellows

A research fellowship foundation which will subsidize graduate study in civil engineering at the University of Maryland has been established by the National Ready Mixed Concrete Association and the National Sand and Gravel Association, Washington, D.C.

The foundation was established in the university's department of civil engineering to promote basic research into the properties of mineral aggregates and concrete, and to study problems related to the sand and gravel and ready-mixed concrete industries.

Fellowships will be awarded to selected civil engineering graduates having outstanding undergraduate records, who have been approved for admission to the university's graduate school.

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Fellows will be appointed for 1 year and reappointment for an additional year is possible. Each fellow will receive a stipend of $2000 plus tuition and other perquisites.

Applications for the fellowships for 1960-61 should be made immediately by contacting Dr. C. T. G. Looney, Department of Civil Engineering, University of Maryland, College Park, Md.

Freeman joins Rocform

Robert L. Freeman has joined Rocform Corp., Detroit, as sales manager. Mr. Freeman was formerly sales manager and technical director of National Block Co. and National Ready Mix, Inc., both of Detroit.

USCC schedules national construction conference

The Construction and Civic Development Department, United States Chamber of Commerce, sponsored the National Construction Industry Conference at the Hall of Flags, Washington, D. C., March 10-11.

Planned as a construction blueprint for the future, the program was planned to give construction industry executives and association leaders a penetrating look into the future, highlighting technological changes in construction and construction market opportunities.

Top industry leaders and experts in the construction field spoke on the program, discussing such subjects as money, manpower, markets, modular building standards, technological re-

search, the highway program, and other important topics.

A highlight of the 2-day meeting was an explanation of the policies of the Federal Reserve Board as they relate to construction by William McChesney Martin, Jr., chairman, Federal Reserve Board.

Austin accepts post at Rice Institute

Walter J. Austin, associate professor of civil engineering at the University of Illinois, has accepted an appointment as professor of civil engineering at Rice Institute, Houston, Tex., effective Sept. 1, 1960.

Dr. Austin has been at the University of Illinois since 1946 as research assistant, fellow, research associate, assistant professor, and associate professor. From 1942 to 1946 he was a structural designer for the Chicago Bridge and Iron Co. at Chicago.

Rawhauser accepts Ceylon assignment

Clarence Rawhauser, who recently retired after 30 year of government employment, has accepted appointment as hydroelectric engineer with the United Nations Technical Assistance Operations on assignment to Ceylon. He will act as adviser to the Ceylonese government in their efforts to develop hydroelectric projects and multiple-purpose projects on several of the principal rivers of Ceylon.

While in the U. S. State Department employ, Mr. Rawhauser spent 7 years on assignment as dams design engineer adviser with the Central Water and Power Commission of the Government of India. He worked closely with design supervisors and construction engineers on many of the large concrete and masonry dams under construction including Bhakra, Airakud, Rihand, and Konya dams. He was previously with the U.S. Bureau of Reclamation.

Rice elected president of ASCE Alaska section

At the 1959 annual meeting of the Alaska section of the American Society of Civil Engineers held in Juneau, Elbert F. Rice, Jr., was elected president. Dr. Rice is the acting chairman of the Department of Civil Engineering at the University of Alaska.

Heinen joins Sika staff

John A. Heinen has joined the technical service department of Sika Chemical Corp., Passaic, N.J., as an engineer.

For the past 12 years Mr. Heinen has been active in almost every phase of concrete production and construction. He has worked in many areas of the world for consulting engineers, architects, and contractors.

Equipment leasing by concrete and rock industry up in 1959

Long-term leasing of production equipment by concrete and rock products firms during 1959 spurted ahead, reaching a total of $3.8 million worth of equipment on lease, a gain of 40 percent over 1958. This was disclosed by Robert Sheridan, president of Nationwide Leasing Co., Chicago.

Total dollar volume of equipment on lease to all industries reached $307 million in 1959, a net gain of about $80 million. This compares to a 1958 gain of $47 million. This does not include cars, trucks, buildings, or railroad rolling stock.

Errata

The following correction should be made in the discussion of "Properties of Nuclear Shielding Concrete," which appeared in the March, 1960, ACI JOURNAL.

p. 924—in Table A the saturated density is given in lb per cu yd; change this to read lb per cu ft. In the footnote under the same table change the word "regarded" to "regraded."

Trunk Sewer Salvaged with Wire Fabric and Shotcrete

ENGINEERING INGENUITY, work force know-how, steel reinforcing fabric, and shotcrete were the ingredients that salvaged an old trunk sewer for the city of Atlanta, at a cost of about $30,000.

Built in 1893 and designed originally to take a fill load of about 15 ft, the three-ring brick trunk sewer found itself bearing as much as 40 ft of fill under the new South Expressway.

First signs of trouble appeared, however, not immediately under the right of way, but west of it. Here, apparently due to the uneven pressure of the fill load, the roof of the old sewer collapsed. Emergency repairs were made by Atlanta's Department of Construction and the old brick trunk was then inspected to determine if other damage had been sustained due to the excess of filled land brought in for the expressway. It was found that the roof had been seriously weakened in several other places under the right of way, with long, deep cracks showing between courses of brick.

Under the one section of the fill the profile of the tunnel had been altered from nearly circular to eliptical. As an immediate safety measure, timber shoring was placed in these areas to prevent further collapse.

In all, 600 ft of the trunk sewer was in a weakened, some places dangerous, condition, and it was decided that the line would have to be rebuilt, repaired, or somehow restored to safe service.

Rebuilding the sewer

At first, city engineers considered placing steel pipe inside the approximately 8 ft diameter trunk sewer. This plan was discarded, however, when it became apparent that use of pipe small enough to slip inside the narrowest necks of the somewhat squashed line would result in too great a loss of capacity.

This condition (irregularities and necked-down portions) led the engineers to their solution for salvaging the trunk—reline it with reinforced concrete. In effect, they decided to build a reinforced concrete pipe in place, but one that would conform to existing contours, and therefore would result in a minimum loss of capacity.

Specified for the relining were two concentric cages of welded wire fabric, embedded in 6 in. of shotcrete, the effective inside diameter of the relined trunk being about 7 ft. The fabric selected for the reinforcement was designated as 2 x 7–3/0//5 and 2 x 7–4/0//5. [The 3- and 4-ought wires (approximately ⅜ in. in diameter) were to be spaced at 2-in. intervals, circumferentially inside the sewer, and the lighter, 5-gage wires, to be every 7 in., "spacing out" the heavier wires.]

The slightly heavier circumferential wires (4-ought) were used for the inner (smaller diameter) cage of the re-

Cage of welded wire fabric has been expanded to nearly full diameter as worker (right) levers it into position to butt against adjacent length

First 3-in. course of shotcrete is being applied over outer cage of welded wire fabric attached to furring strips. A second cage of steel fabric was then placed and a inner 3-in. layer of shotcrete placed

lining, this being the area of greater stress due to earth loads above. (The weights of reinforcing specified are almost identical to that used in manufacturing the more conventional precast 84-in. diameter reinforced concrete pipe.)

The actual work of salvaging the trunk sewer was accomplished by city work forces during the 1959 summer season, and their know-how and willingness to tackle something new contributed to the smooth progress of the job. It took 2 weeks to place the wire fabric cages. Six weeks were estimated for shotcreting but excessive rain in the latter part of August delayed this phase of the work somewhat.

The only major construction procedure to be changed concerned the size of the sheets of fabric to be placed. The reinforcement came to the job site in 4 ft wide rolls (standard width for concrete pipe), from which circumference-length pieces were to be cut for forming into cages.

It became apparent immediately, however, that most of the manholes through which all material had to be lowered to the trunk were too small in diameter to accept 4 ft wide lengths. The 25-ft (approximate circumference) lengths therefore, were cut in half, and lowered with little trouble.

Once into the sewer, the lengths were coiled into manageable sized hoops, rolled along the invert to position, turned 90 deg, and allowed to expand to fit the circumference of the trunk. The cages were secured in position by nailing to furring strips, fastened to the inner walls, top, bottom, and sides, of the old three-ring brick sewer. The lengths were butted and wire-tied to adjoining lengths, and the ends lapped and tied to assure continuity of circumferential reinforcing.

To assure most effective use of the fabric reinforcing in resisting loads, the outer cages were lapped at the bottom but the inner cages were lapped at the upper quarters of the sewer—alternating at "10 and 2 o'clock."

When about 200 ft of outer cage had been placed, shotcreting started. The air compressor and mixer were truck mounted, and the mix was fed through hoses to the nozzlemen below. After getting a working procedure established, gunning went on at about 8 cu ft an hr, with about 100 ft of two-layer concrete going on in a week.

After the first 3-in. layer of concrete had been shotcreted, 2 days elapsed for setting up. This was followed by placement of the inner cage of steel fabric, and the second or inner 3-in. layer of concrete.

Final step in the restoration of the old sewer was the replacement of the temporary sections of corrugated pipe at the scene of the original cave-in with 5 ft of conventional plant manufactured reinforced concrete pipe.

Credits

Ray A. Nixon is chief of Atlanta's Department of Construction; M. B. Nixon, assistant chief of construction; and R. W. Respass, engineer of sewers. The shotcreting was handled by Western Waterproofing Co. of Atlanta.

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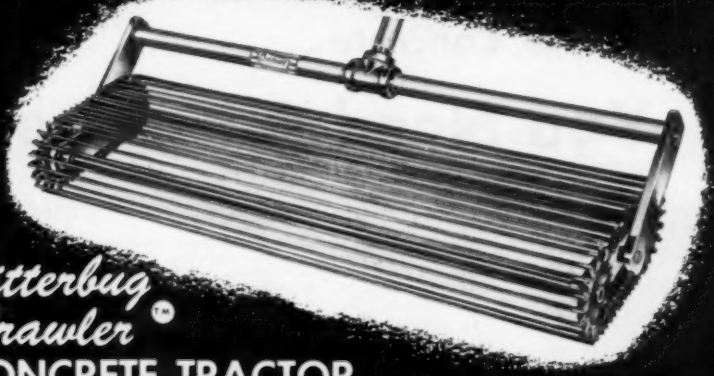

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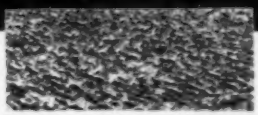
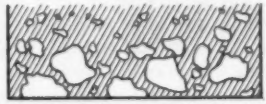
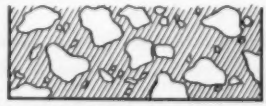


Close-up photo of Tractored surface shows how concrete Tractor's parallel bars press straight down into mix, allowing medium and fine particles to rise around them. No other method leaves surface prepared as shown in this photo!

Cross sectional diagram shows how Tractors rods "ride the rock," putting the larger aggregate just beneath surface, to improve aggregate distribution and help to create improved concrete.



Cross section of over-tamped slab shows coarse aggregate unevenly distributed and too far from surface. Such structure makes for unsatisfactory wear, as well as surface defects.



Cross section of untamped slab shows the coarse aggregate right at surface, waiting to catch blade of finishing trowel. Finished slab with this structure is more likely to spall quickly.

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Finnegan named field engineer for Master Builders

Edward C. Finnegan has been named field engineer for the Indianapolis territory of The Master Builders Co., Cleveland. He joined the organization in 1955 and served as field sales representative in the Syracuse territory until his present appointment.

AED holds 41st annual meeting

Over 4000 managerial delegates, representing some 700 distributor firms and 350 manufacturing companies within the United States, Canada, and other countries, gathered at the 41st annual meeting of the Associated Equipment Distributors, January 24-28, in Chicago.

Jewel A. Benson, Benson Tractor Co., Houston, was elected to serve as president of AED for 1960. Other officers elected for the coming year were Herbert J. Mayer, Western Machinery Co., San Francisco, senior vice-president; Richard F. Newlin, Newlin Machinery Corp., Kansas City, Kan., vice-president; Braxton Blalock, Jr., Blalock Machinery and Equipment Co., Atlanta, vice-president; R. Boyd, Somerville, Ontario Equipment and Supply Ltd., Toronto, Ont., Canada, vice-president: and W. R. Parnell, Construction Machinery Corp., Shreveport, treasurer.

University of Illinois faculty promotions

ACI members on the University of Illinois civil engineering faculty receiving promotions effective in the fall of 1959 include: John W. Briscoe from assistant department head to associate department head; William J. Hall, John D. Haltiwanger, and Anestis S. Veletsos from associate professor to professor; Mete Sozen from assistant professor to associate professor; Alfredo Ang and Arthur Feldman from research associate to assistant professor; Melvin T. Davisson and Richard Eppink from research assistant to instructor; and J. G. MacGregor and Wallace W. Sanders from research assistant to research associate.

Thirty-three members of the staff are members of ACI.

Schemm elected president of Huron Portland Cement

H. Ripley Schemm, formerly executive vice-president, was recently elected president of Huron Portland Cement Co., Detroit, following the retirement of Paul H. Townsend.

Mr. Schemm joined the company in 1925. In 1942 he was named assistant general manager and in 1949 was appointed vice-president in charge of operations. Following the purchase of Huron by National Gypsum Co. in 1959, Mr. Schemm was elected executive vice-president.

Bahmeier honored

Herman F. Bahmeier, regarded as "dean" of the Bureau of Reclamation's construction engineers, recently received the Department of the Interior's highest honor, the Distinguished Service Award "in recognition of signal engineering achievements which are a credit to the federal government."

Mr. Bahmeier retired last May as head of the projects office at Grand Junction, Colo., after a long and distinguished career with the Bureau of Reclamation dating back to 1930. Many of his projects involved unusual and difficult engineering and construction problems never before encountered.

Pan American Highway Congress scheduled in Bogota, May 20-29

The 8th Pan American Highway Congress will be held in Bogota, Colombia, May 20-29.

Because of the imminent opening of the Pan American Highway as far as the Panama Canal, and recent developments relative to the gap in the Darien region of Panama and adjacent areas in Colombia, it is expected that

important conclusions will result from this inter-American specialized conference, bearing on the ultimate completion of the great "Avenue of the Americas."

Pursuant to a resolution adopted by the Council of the Organization of American States, an official invitation has been forwarded by the Secretary General, Dr. José A. Mora to members of international organizations and prominent specialists interested in highway development to attend as observers. Further details regarding the Congress are available from Francisco J. Hernandez, secretary, Pan-American Highway Congress, Pan American Union, Washington 6, D.C.

ASCE to hold structural mechanics conference

The Engineering Mechanics Division of the American Society of Civil Engineers will hold a conference on structural mechanics at Purdue University on Thursday and Friday, May 5 and 6, 1960. Three 1/2-day technical sessions are planned for this meeting. The three general areas to be covered by speakers are members and frames, plasticity, and dynamics.

Speakers on the program for the first session on the afternoon of May 5 include E. F. Masur, University of Michigan, and L. H. Donnell and I. C. Chang, Illinois Institute of Technology, discussing stability of frames in the presence of primary bending moments; Alfredo Ang, University of Illinois, will speak on the analysis of frames with nonlinear behavior subjected to lateral deformations; Morris Ojalvo, Lehigh University, will speak on restrained columns; and J. E. Goldberg and J. L. Bogdanoff, Purdue University, will base their talk on normal and torsional loading of circular I-beams.

The Friday morning session on plasticity will present papers by L. B. Kriz and S. L. Lee, Northwestern University, on ultimate strength of over-reinforced beams; G. G. Meyerhoff, Nova Scotia Technical College, Halifax, Canada, on the bearing capacity of floating ice sheets; B. C. Ringo, Michigan State University, on load replacement in plastic analysis; and P. S. Symonds, Brown University, and B. G. Neal, University College of Swansea, Wales, on traveling loads on rigid-plastic beams.

The session on dynamics, Friday afternoon, includes papers by F. L. Tyder, Republic Aviation Corp., Farmingdale, N.Y., on electrical energy analogs of vibrating beams; M. G. Salvadori and Richard Skalak, Columbia University, and Paul Weidlinger, consulting engineer, New York, on stress waves and shock in locking media; and G. V. Berg and S. S. Thomaides, University of Michigan, speaking on energy relations for elasto-plastic systems responding to earthquakes.

Pennsylvania State to hold atomic shelter seminars

Pennsylvania State University will conduct two engineering seminars on atomic shelter this summer.

The first, July 10-22, will deal with the architectural and engineering planning aspects. This 2-week short course is designed for architects and engineers who are now or will become involved in planning and preliminary design aspects of buildings, shelters, and facilities to resist the effects of nuclear weapons. The course will include a summary of effects of atomic weapons, including blast, and nuclear and thermal radiation, functional requirements for protection, the relationship of various protection criteria to total system planning, and planning of integrated shelters systems with regards to the architectural, structural, electrical, mechanical, and sanitary subsystems.

From July 24 to August 5 will be the short course dealing with structural engineering and radiation shielding aspects. Topics will include analysis and design of structural systems and radiation shielding systems of buildings, shelters, and facilities to resist the ef-

fects of nuclear weapons. There will also be a brief summary of atomic weapon effects data, blast loading of various structural systems types, ultimate strength theory, dynamic analysis and design methods, distribution, intensity, and energy levels of nuclear radiation.

Further information is available from the seminar chairman, Gifford H. Albright, assistant professor of architectural engineering, Pennsylvania State University, University Park, Pa.

Larsen named chief design engineer

Ralph A. Larsen was recently appointed chief design engineer of Stone and Webster Engineering Corp., Boston and New York.

Mr. Larsen, who joined the firm in 1936 as a draftsman, succeeds Charles D. Lilburn, who has been named design consultant.

Soiltest establishes Swiss subsidiary

Soiltest, Inc., Chicago, has announced the organization of a subsidiary, Soiltest International S.A. of Lausanne, Switzerland. The Swiss corporation will direct sales and distribution for the company's European, African, and Middle Eastern markets.

Raymond International names southeast area manager

James J. Mennis has been named southeast area manager of Raymond International Inc.'s heavy construction division. He will operate from Raymond's New Orleans office, and will supervise sales and installation of the company's line of prestressed products, particularly cylinder piles for highway, port, and offshore structures.

New book tells

Where . . .

How . . .

to place reinforcing bars

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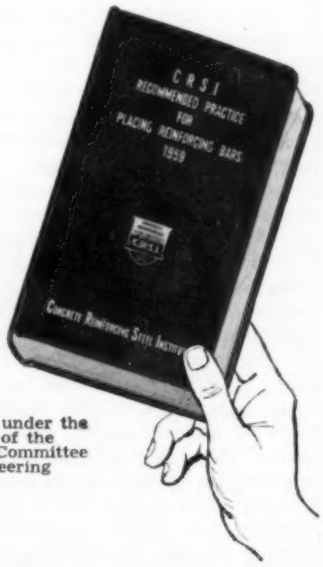

Prepared under the direction of the C.R.S.I. Committee on Engineering Practice.

CONCRETE REINFORCING STEEL INSTITUTE
38 South Dearborn Street (Dept. R), Chicago 3, Illinois

L. C. Porter, engineer of the Bureau of Reclamation's Engineering Laboratories at Denver, (left to right) and J. R. Granger, field engineer of the Flaming Gorge Unit, J. E. Backstrom, engineer of the concrete laboratory, and J. R. Walton, project construction engineer, of the Flaming Gorge Unit at Dutch John, Utah, are shown before the laboratories' pilot plant for heavy media separation of aggregate. The plant was shown to participants during the Sixth Construction Engineers' Conference of the Bureau of Reclamation.

USBR staff attend annual briefing courses

About 120 Bureau of Reclamation engineers and technicians who inspect construction work throughout the western United States recently attended courses at the Bureau's engineering center in Denver. The courses are held annually to assure uniformity in investigations of concrete and earth materials, and in the inspection and control of quality of construction work on Bureau projects. Value of construction contracts now in force is$345 million.

Instructors for the series of lectures were engineers and scientists of the staff of Grant Bloodgood, assistant commissioner and chief engineer. Facilities for instruction are provided in the Bureau's central engineering laboratories. The laboratories, which now occupy a 4-acre site at the Denver Federal Center, were established in 1930 to obtain information needed for the design and construction of Hoover Dam. They have achieved an international reputation in the research aspects of water resource development. Today, they are serving design and construction engineers on such major developments as the 700-ft high Glen Canyon Dam on the Coronado River Storage Project, and the Trinity River Division of the Central Valley Project of California, and units of the seven-state Missouri River Basin Project.

PCA advances two in research and development division

The Portland Cement Association, Chicago, has announced the appointment of Ivan L. Tyler as research counselor in the Research and Development Division. He has been succeeded as manager of the Field Research Section by Paul Klieger, formerly senior research engineer.

In his new post, Mr. Tyler will be freed of administrative detail so that his exceptional experience and training in concrete technology may be more fully applied to advanced research and counseling. His broad experience in concrete construction has included positions as hydroelectric construction engineer with Southern California Edison Co., materials engineer in charge of all concrete work for the Tennessee Valley Authority, and chief materials engineer for the Pennsylvania Turnpike Commission.

Mr. Tyler will continue in his capacity as secretary to the advisory committee to the Long-Time Study of Cement Performance in Concrete, the largest research project in which the association is engaged. Mr. Tyler is currently serving on six ACI committees.

Paul Klieger, newly appointed manager of the Field Research Section, is well known for his original and useful research in concrete technology. He also serves as chairman or secretary of

several important committees of national societies concerned with cement and concrete science, and is a member of ACI Committee 613, Recommended Practice for Proportioning Concrete Mixes. Before coming to PCA as a research engineer, Mr. Klieger worked with the Wisconsin State Engineer's Office and with the Department of Mechanics of the University of Wisconsin.

Tatlow elected president of AICE

Richard H. Tatlow III, president of Abbott, Markt and Co., New York engineers and designers, was recently elected president of the American Institute of Consulting Engineers.

Gerald T. McCarthy of Tippets, Abbett, McCarthy, and Stratton, New York, and Harold M. Lewis, New York, were elected vice-presidents of the institute.

Others elected as members of the governing council are: John G. Frost of Wiggs, Walford, Frost and Lindsay, Montreal, Canada; Ray E. Lawrence of Black and Beatch, Kansas City, Mo.; and Gilbert I. Ross of Ross and Co., New York.

Rosenburgh elected Turner secretary

Carleton F. Rosenburgh was recently elected secretary of Turner Construction Co., New York. Mr. Rosenburgh has been with the company for 34 years and has been a director since 1947 and a vice-president since 1953.

Jenny joins Expanded Shale Clay and Slate Institute staff

Daniel P. Jenny, for 10 years a structural engineer with the Portland Cement Association, has been added to the staff of the Expanded Shale Clay and Slate Institute, Washington, D. C.

Mr. Jenny is a member of ACI Committee 324, Precast Reinforced Concrete, Thin Sections.

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Maguire appoints new distributor

Walter Maguire Co., New York, has appointed Akron Welding and Spring Co., Akron, Ohio, as a distributor for its heavy-duty industrial flooring products. The distributor will handle Maguire's complete line of emery aggregate-based floor repair and resurfacing materials, serving a number of counties in northeast Ohio.

Cohen becomes Rogers' associate

Eli Werner Cohen has been admitted as an associate in the firm of Paul Rogers and Associates, Inc., Chicago consulting engineers. This is in line with company policy that staff engineers become associates upon passing the state structural engineering registration examination. Mr. Cohen was also appointed assistant chief engineer.

LOOKING AHEAD

May 4-8, 1960 — Cleveland Convention, American Society of Civil Engineers, Hotel Cleveland, Cleveland, Ohio.

May 5-6, 1960 — Structural Mechanics Conference, American Society of Civil Engineers, Purdue University, Lafayette, Ind.

May 20-29, 1960—Pan American Highway Congress, Bogota, Colombia

June 16-22, 1960—Third International Congress of Precast Concrete Industry, Sankt Erikshallen, Stockholm, Sweden

June 20-22, 1960—FIP-RILEM Symposium on Injection Grout for Prestressed Concrete, Norges Tekniske Hogskole, Trondheim, Norway

June 20-24, 1960 — Annual Meeting, American Society of Engineering Education, Purdue University, Lafayette, Ind.

June 26-July 1, 1960 — Annual Meeting and Apparatus Exhibit, American Society for Testing Materials, Chalfonte-Haddon Hall, Atlantic City, N. J.

June 27-July 1, 1960—Sixth Congress, International Association for Bridge and Structural Engineering, Stockholm, Sweden

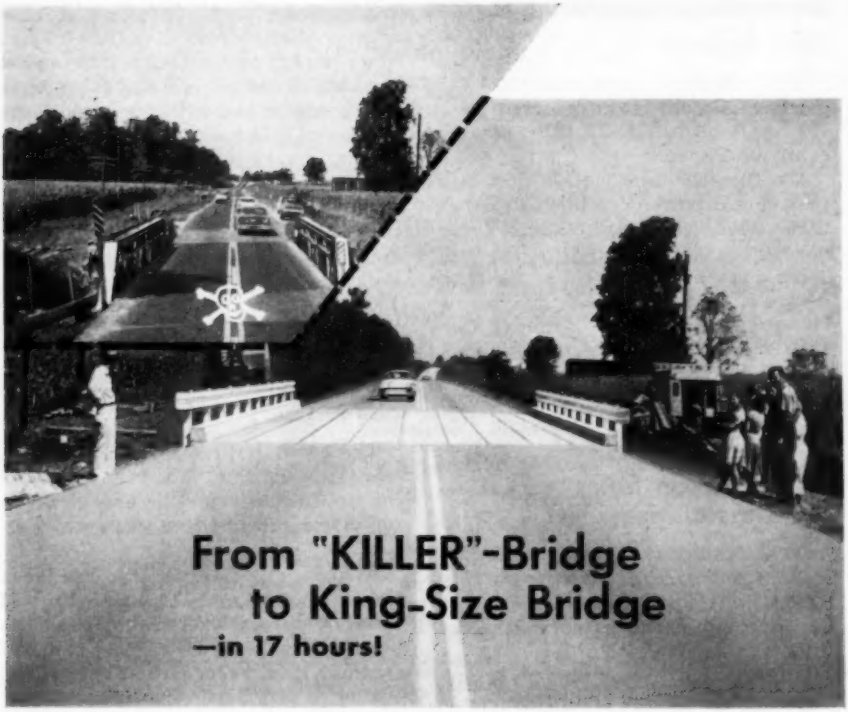
July 10-22 and July 24-August 5 — Engineering Seminars on Atomic Shelters, Pennsylvania State University, University Park, Pa.

July 11-18, 1960 — Second World Conference on Earthquake Engineering, Science Council of Japan, Tokyo and Kyoto, Japan.

July 17-21, 1960—RILEM International Symposium on Concrete and Reinforced Concrete in Hot Countries, Israel Institute of Technology, Haifa, Israel

Aug. 15-26, 1960 — Summer Institute on Nondestructive Testing, Sacramento State College, Sacramento, Calif.

Oct. 31-Nov. 1-2, 1960—13th Regional Meeting, American Concrete Institute, Pioneer Hotel, Tucson, Ariz.



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Otto Buehner

Otto Buehner, president of Otto Buehner Co. and the Buehner Block Co., both in Salt Lake City, died recently in Phoenix.

Mr. Buehner founded his first business venture, the Otto Buehner Co., in 1926 and specialized in precast building facings.

He was a past president of the Mosai Institute, and a director and former vice-president of the National Concrete Masonry Association. As a member of the Salt Lake Building Congress, he received a meritorious service award from this organization in 1957.

Ontario group forms trade association

Ontario manufacturers of centrifugally cast concrete products recently formed the Centrifugally Cast Concrete Institute with headquarters in Thorold, Ont., Canada.

The institute has as objectives promotion of the use of centrifugally cast concrete products, standardization and continued improvement of design, an exchange of practical knowledge among its members and associated industries and government agencies.

The initial promotional efforts will be concentrated on spun concrete poles which are being increasingly used for lighting standards, power distribution, and communication systems.

Ninth national clay conference scheduled

The Ninth National Clay Conference, sponsored by the Clay Minerals Committee of the National Academy of Sciences—National Research Council, will be held at Purdue University, Lafayette, Ind., Oct. 6-8, 1960.

Two special symposia of invitational papers on the subjects of "Engineering Aspects of Physico-Chemical Properties of Clays" will feature contributions on soil mechanics and "Clay-Organic Complexes," presenting basic studies of clay-organic systems in civil engineering, paper and petroleum industries, in soil science, and other areas. The program also includes general sessions, and original contributions on any aspect of clay mineralogy are invited.

Title and abstracts of contributions to the general sessions should be submitted in duplicate to Dr. J. L. White, Agronomy Department, Purdue University, Lafayette, Ind., by June 1, 1960. Abstracts should be limited to 250 words.

Sika announces new officers

The board of directors of Sika Chemical Corp., Passaic, N.J., has announced the appointment of four executives to top administrative and research positions.

Andrew G. Clauson, Jr., has been elected chairman of the board. He will continue as treasurer. Hugh Sudall has been elected secretary of Sika and will continue to serve as assistant treasurer. Walter V. D. Bayer has been elected assistant secretary.

Raymond J. Schutz has been promoted to vice-president in charge of research and development from the position of technical director. Active in ACI technical committee work, Mr. Schutz is currently a member of ACI Committee 717, Practice in Low-Pressure Steam Curing, and Committee 805, Application of Mortar by Pneumatic Pressure.

Holway merges with Tulsa engineering firm

W. R. Holway and Associates, Tulsa's oldest engineering firm, and Cornett, Wood and Associates, also of Tulsa, have merged to form Holway Engineers, Inc.

W. R. Holway heads the new company which will specialize in consultant work in sanitary, structural, hydraulic, mechanical, and electrical engineering.

Membership in the American Concrete Institute

To facilitate prospective members in joining the Institute, membership application forms are provided. Present Members may aid by bringing these forms to the attention of those who may profit from membership advantages. All who have an interest in concrete are eligible for membership. The grades of membership are described below.

Members have at hand in Institute publications the most complete fund of knowledge on concrete. The ACI Journal provides them with the latest information and ACI special publications provide them with the complete picture of specific problems. Through conventions, and regional and area meetings, they are afforded the opportunity of meeting those whose experiences provide the new information, and of exchanging ideas with them.

ACI's world-wide membership is growing in extent and participation —traveling a common road toward better, more economical and durable concrete structures. ACI provides a common ground in the search for and use of new "working tools" in concrete design, manufacture, and erection—and its interpretation.

Individual Members (U.S. and Possessions, Canada, Mexico, Central America, and West Indies)	**$20.00**
Individual Members (All other foreign countries)	**16.00**
Corporation Members	**65.00**
Junior Members—nonvoting (under 28)	**10.00**
Contributing Members	**135.00**
Student Members—nonvoting (under 28)	**5.00**

Please enclose remittance with application (cut here)

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The undersigned hereby applies for admission to the American Concrete Institute as ☐ *Individual* ☐ *Corporation* ☐ *Contributing* ☐ *Junior* ☐ *Student Member and agrees to be governed by the Charter and Bylaws.*

Name and complete mail address of proposed membership (Address to which Journal is to be mailed—please letter) _____

_____

For Corporation Membership, ACI representative will be _____

Date of Birth (Juniors and Students only) _____
Year Month Day

College or University attending (Students only) _____

_____ _____
(Date of graduation) (Proposed by)

Signature_____

For our records, please complete both sides of application.

NOTES on Membership Classification

The ACI advertising and editorial departments need definite information concerning job title, classification, business affiliation, and principal responsibility of all members. Thus, the information requested on the classification form below is especially important.

The applicant should designate his title or position such as: construction superintendent, research director, technician, draftsman, structural engineer, inspector, plant superintendent, highway engineer. The occupation of the applicant should be that which is **most frequently** performed. The principal responsibility of the applicant is that specific area of his job for which he is **primarily concerned.**

Classification is not based on what interests you, but on what you do—what office or job you fill. When completing the form below, please check the one item in each section that is most applicable to that particular section.

ACI editors want to know your interests—they welcome suggestions as to what you'd like to see discussed in the ACI Journal and of the possible sources. Please attach a separate note or letter.

MEMBER CLASSIFICATION

JOB TITLE _____

OCCUPATION (Check the one most applicable)

☐ Arch ☐ Engr ☐ Construction Supervision ☐ Plant Management or Supervision ☐ Teaching ☐ Student ☐ Other (please state) .....

EMPLOYER

☐ Architect ☐ Contractor ☐ Consulting Engr ☐ Engr Firm ☐ Manufacturer or Producer (specify product) .....

Government ☐ Fed ☐ State ☐ County ☐ City ☐ Educational Institution ☐ Commercial Testing Laboratory ☐ Public Utility ☐ Trade Assn ☐ Library ☐ Other (please state) .....

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☐ Other (please state) .....

Do you ☐ Specify ☐ Authorize ☐ Recommend, purchase of materials or equipment?

Honor Roll

Jan. 1-Mar. 31, 1960

Let's keep the membership trend spiraling. YOU can further the growth and prestige of the Institute by proposing new members.

If each ACI'er would introduce one new member to the Institute, our membership would soon double. Add your name to the Honor Roll next month.

Point System

1 point for Student; 2 points for Junior; 3 points for Individual; 4 points for Corporation; and 5 points for Contributing.

Alfonso Marin E.	30
Samuel Hobbs	19
Faraj Tajirian	10
Walter H. Price	9
Joaquin Spinel L.	7
Jose Luis Montemayor	6
Gene M. Nordby	6
George B. Southworth	6
Pedro M. Bassim	5
W. S. Cottingham	5
John E. Heer, Jr.	5
Antonio A. Henson B.	5
T. C. Kavanagh	5
James A. McCarthy	5
J. F. Toppler	5
Felix Colinas Villoslada	4
William W. Karl	4
Joe W. Kelly	4
Henry A. Lepper, Jr.	4
Pastor B. Tenchavez	4
Amos Atlas	3
J. E. Backstrom	3
Ira M. Beattie	3
George B. Begg, Jr.	3
Alan Carter	3
Fernando de Angulo	3
H. C. Delzell	3
Marco Estrada	3
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R. J. Fisk	3
Russell S. Fling	3
Frank D. Gaus	3
Hans Gesund	3
Fabian Guerra	3
G. M. Idorn	3
Robert J. Kadala	3
Karl Kaspin	3
Clyde E. Kesler	3
F. R. Killinger	3
John C. King	3
E. V. Konkel	3
William J. Krefeld	3
L. R. Lauer	3
Howard Losey, Jr.	3
John C. McCoe	3
W. J. MacDonald	3
M. F. Macnaughton	3
Luis F. Magrina	3
Roman Malinowski	3
Ignacio Martin	3
W. E. Moulton	3
Poul Nerenst	3
John D. Paterson	3
T. Paulay	3
E. A. Peterson	3
Russell Porter	3
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Frank Randall, Jr.	3
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H. M. Schwartz	3
Harold J. Sexton	3
M. F. A. Siddiqui	3
A. L. Small	3
John D. Smith	3
S. Szalwinski	3
F. K. Taskin	3
D. A. Van Horn	3
Ellis S. Vieser	3
Cedric Willson	3
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Ward W. Engle	2
G. Grenier	2
Martin J. Gutzwiller	2
Robert B. Harris	2
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William W. Hotaling, Jr.	2
Fred W. Jacobs	2
I. Karni	2
Simon Lamar	2
Howard R. May	2
Abel Moreno Przespolewski	2
R. R. Neal	2
Carlos Luis Nebreda	2
Carlos Isunza Ortiz	2
Raoul E. Pallais	2
Gerald F. Paulson	2
Luis G. Restrepo S.	2
Walter D. Rudeen	2
C. P. Seiss	2
E. C. Sword	2
Rogelio Bonilla Torres	2
J. Raymond Watson	2
Leon A. Yacoubian	2
Roger M. Zimmerman	2
Antonio Zuniga Ayala	2

New Members

The Board of Direction approved applications in the following categories: 71 Individual, 8 Corporation, 14 Junior, and 27 Student, making a total of 120 new members. Considering losses due to deaths, resignations, and nonpayment of dues, the total membership on Feb. 1, 1960, was 10,173.

INDIVIDUAL

ABBOTT, H. H., El Paso, Texas (Struct. Engr., J. E. Morgan & Sons)

APPEN, H. V., Nashville, Tenn. (Vice-Pres., J. A. Jones Constr. Co.)

ARCEIVALA, SORAB J., Bombay, India (Principal & Sec'y., Victoria Jubilee Tech. Institute)

ARMSTRONG, ARGYLE E., Wenatchee, Wash. (Partner, Armstrong & Armstrong)

BACKUS, RICHARD A., Birmingham, Mich. (Tech. Svc. Engr., Peerless Cement Co.)

BALLIF, BRENT P., Pocatello, Idaho (Struct. Engr., L. H. Ballif Assocs.)

BALTAY, M., Belmore, NSW, Australia (Design Engr.)

BANDIERA, L. J., Kitimat, B.C., Canada (Wks. Engr., Aluminum Co. of Canada Ltd.)

BOLDUC, ROBERT, Cali, Colombia (Tech. Dir., ISOROC Ltd.)

BROAD, JOHN F., Austin, Texas (Owner, John Broad Constr. Co.)

BROWN, WILLIAM C., Lyndhurst, Ohio (Ass't. Prod. Sales Coordinator, Master Builders Co.)

BURG, WALTER A., Tucson, Ariz. (County Engr., Pima County Hwy. Dept.)

BUSH, EDWARD G. W., Cleveland Hts., Ohio (Prod. Dev. Engr.)

CARLSON, LAWRENCE A., East Chicago, Ind. (Field Engr., Carlson-Ried Bldrs., Inc.)

CLARK, ARTHUR E., JR., Cranston, R.I. (Pres., J. Adolf Johnson, Inc.)

CROSON, MELTON A., Chester Depot, Vermont (Constr. Insp.)

DIBBLE, JOHN T., Ventura, Calif. (Cons. Struct. Engr.)

EEMAN, GUNNAR, Columbus, Ohio (Cons. Struct. Engr., Russell S. Fling)

EINSWEILER, FRANK L., Galena, Ill. (Gen'l. Mgr., V & E Constr. Co.)

EMERICK, PAUL E., Portland, Ore. (Opers. Mgr., Paul B. Emerick Co.)

ERICKSON, JOHN A., Los Angeles, Calif. (Constr. Struct. Engr.)

FLECK, LUIS, Ciudad Trujillo, D.N., Republica Dominicana

FREEMAN, FLOYD J., Lawton, Okla. (Partner, Freeman Constr. Co.)

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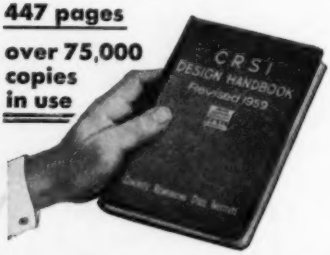

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Tools, Materials, Services

Under this heading note is made of producer literature and products of presumed technical interest to ACI users of tools, equipment, materials, accessories, and special services.

Form clamp and stake

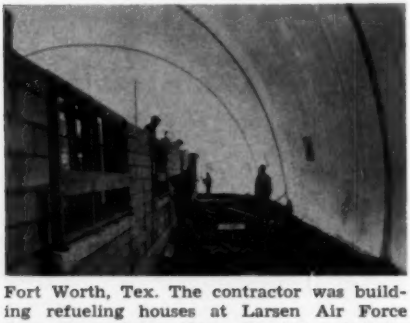
Lev-A-Lok, a forming device for sidewalks, driveways, and other jobs using 4- and 6-in. forms, has been introduced by Chesley Industries.

The combination steel stake and clamping tool with built-in stake puller is made of rustproof steel. The clamping device fits standard 2 x 4-in. and 2 x 6-in. lumber and firmly holds splices, as well as all other parts of the form, rigid throughout entire job according to manufacturer.—Chesley Industries, Inc., 24777 Telegraph Road, Detroit 41, Mich.

Airhouses

Seattle Tent and Awning Co. are manufacturing air-supported fabric domes, which are balloon-like structures currently used for everything from aircraft repair hangars to construction shelters.

The airhouse, of vinyl coated nylon fabric, is entirely supported by air, requiring no interior supports regardless of the width or length of the house. Photo shows fabricated airhouse being used by Leslie-Miller, Inc.,

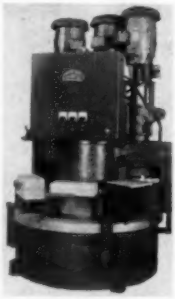


Fort Worth, Tex. The contractor was building refueling houses at Larsen Air Force Base, Moses Lake, Wash. The job called for laying up concrete block structures in subfreezing weather. This 60 x 110 x 30-ft high airhouse was kept at ideal drying temperatures by heating the air as it was blown in by the two 2000-cfm Electro-Watt blowers. As each block house was completed the airhouse was deflated, moved and set up for construction of another.

A unique feature about these structures is the way in which they may be erected and taken down. Much as a balloon is inflated, the airhouse is blown full of air to support it. After fastening perimeter to ground, inflation takes an hour or less, depending on the volume capacity of the blowers and the size of the structure. Air under pressure of 1 lb per sq ft keeps it up. A complete 40 x 80-ft airhouse, with blowers for maintaining it, can be carried in a standard station wagon.—Seattle Tent and Awning Co., 310 Westlake North, Seattle 9, Wash.

Automatic surfacer for precast block and tile

Ty-Sa-Man Machine Co. announces the Carousel, automatic surfacer for precast block and tile, faced or regular.



The Carousel requires only four foundation bolts and drainage for simple erection. Available with three to five heads, each directly connected with 20 hp motors; single water valve serves all grinding heads. Unit is 60 in. in diameter, 9 ft 8 in. high, having maximum weight of 10,500 lb with three heads.

With the variable speed control, one operator can turn out from 2 to 14 units per min according to manufacturer.—Ty-Sa-Man Machine Co., 1043 White Ave., Knoxville, Tenn.

Steel and plastic form coating

Brad Chemical has introduced Uni-Form, a coating compounded specifically for use on nonabsorbent form faces. The compound allows the user to strip forms cleanly, regardless of mix or type of concrete used says the company. It can be applied with mechanical or hand sprayers, or can be brushed or mopped on. It is colorless and will not stain, and according to the manufacturer, forms coated with Uni-Form may be used more than once without recoating. It comes ready mixed.—Brad Chemical, Inc., 111 W. Washington St., Chicago, Ill.

Wet-or-dry terrazzo grinder

A 1-hp high speed terrazzo grinder with fully enclosed motor is mounted on a four-leg caster base with composition casters to prevent scratching of floors. A lightweight, 10-ft flexible shaft gives the machine good maneuverability and convenience on the job.

A variety of accessories are available, all equipped with quick-change connectors making it possible to change from wet or dry angle spindles to straight grinding spindles or cove base grinding heads in a few seconds. The entire machine weighs 65 lb.—Wyzenbeek and Staff, Inc., 223 N. California Ave., Chicago 12, Ill.

Towercranes

Formation of a new subsidiary company, Universal-Liebherr, Inc., which will handle United States sales of Towercranes for building construction, has recently been announced.

Towercranes range from approximately 40 ft to 293 ft 6 in. in height with load capacities up to 24,000 lb. Traveling on wide-gage tracks and entirely electrically operated, Towercranes can boom out over an entire building area permitting "spot-placement" of required building materials according to manufacturer.

Design of its vertical tower enables the crane to begin a job in a telescoped-in position for construction of the lower floors. Then, under its own power, telescope out as the building goes up. Transporting of crane from job to job is accomplished by adaptation of standard pneumatic-tired road transport equipment. — Universal-Liebherr, Inc., Zelienople, Pa.

Plasticized cement for splicing concrete pile

Florok's plasticized cement has been introduced for splicing concrete pile. The "melt and pour" fast setting cement is said to fill all the requirements of an excellent bonding material. Florok's plasticized cement melts to a light fluid consistency between 265-290 F.

The following procedure has been followed in splicing concrete pile: (1) base is drilled, or dowel holes are precast to receive reinforcing dowels previously cast into top section; (2) the two units are then lined up properly and a jig or boot is placed around the joint and securely locked in place; (3) the plastic cement is melted and ladled into spouts of jig or boot; (4) allowed to set for a minimum of 15 min the jig is then removed and work resumed.—The Chargar Corp., 1013 Dixwell Ave., Hamden, Conn.

Steel furring members cast in concrete channel legs

Long-span concrete channel slabs for floor and roof construction with built-in steel furring members have been developed by George Rackle and Sons Co. The long-span channel slabs, available in lengths of 32 ft, are constructed with a continuous nailing member strip inserted in one leg. The nailing strip is of rigid, zinc-coated, roll-formed construction. Annular barbed nails driven into the steel channel are held permanently in place under tension of the spring steel.

As the channel slabs are 2 ft wide, a nailing surface on 24-in. centers is obtained permitting the fastening of 1/2-in. gypsum board directly to the concrete channel without need for intermediate furring strips. Wood furring strips can be fastened to the nailing insert to take acoustical tile ceilings either cemented

or nailed to the furring strips. A third method permits fastening 24 x 12-in. kerfed acoustical tile directly to the nailing inserts. Metal splines placed in the kerfs as the tile is installed create a rigidly interlocked fireproof system according to company spokesman.

The Rackle long-span channel is available in standard 24-in. widths (6, 8, and 12 in. deep). Clear span lengths are available to 32 ft.—George Rackle and Sons Co., Newburg Station, Cleveland 5, Ohio.

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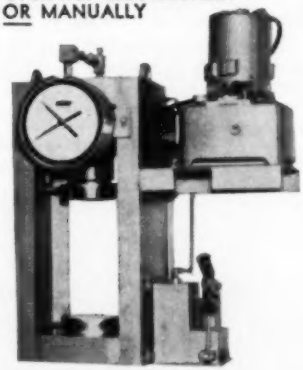

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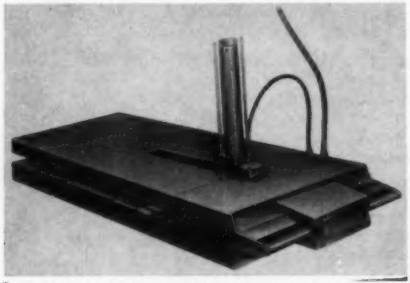
Six-block cuber

A six-block cuber has been developed by Lithibar Co. The principal advantage is said to be its ability to enter the rack from one side and remove the double-tiered block in one operation, six blocks at a time.



The unit is hydraulically operated to handle 4- to 12-in. solids or bricks with push bottom controls for lifting, lowering, clamping, and releasing conveniently located for operator. The clamping arrangement is such that the front three blocks, the rear three blocks, or all six blocks can be released at will.

The supporting cylinder is attached to a 14-ft cross track traveling on two 40-ft longitudinal tracks, giving complete freedom of movement throughout the cubing area.—Lithibar Co., Holland, Mich.

Fork-lift truck

An indoor/outdoor, 6000-lb capacity fork-lift truck called the Pacer is offered by American Road Equipment Co. The vehicle is available with either 10-ft standard lifting mast or optional 7-ft mast.

Features include 14:00 x 24:00 tires, power steering, torque converter, hydraulic lift,

front wheel drive, and short wheel base. The unit is powered by a 73 brake hp F-226 Continental engine; top speed is 30 mph.—American Road Equipment Co., 4201 North 26th St., Omaha, Neb.

Literature Available

Pertinent details on the latest equipment and products on the market are available in recently released literature. Exact titles of the booklets and catalogs are indicated in capital letters. They may be requested directly from the manufacturers listed below.

POZZOLITH EMPLOYED IN LIGHTWEIGHT CONCRETE (MBR-P-14)—Features 13 construction projects with discussion covering the use of lightweight concrete for columns, beams and floor slabs, multistory structures, thin shell concrete, and bridge decks. Job reports describe the role played by Pozzolith on these projects.—The Master Builders Co., Cleveland 3, Ohio.

NON-SHRINK GROUTING (E-1d)—Describes grouting techniques with Embeco nonshrink grout. The bulletin outlines and illustrates common methods of grouting different types of equipment, the mixing and placing of grout, and cold and hot weather grouting.—The Master Builders Co., Cleveland 3, Ohio.

X-RAY METHODS—Wall chart showing ten basic x-ray techniques used today for industrial quality control and scientific research. Chart shows a simplified diagram for each one of the techniques with explanatory notes and brief discussion of the fields of application.—Philips Electronic Instruments, 750 South Fulton Ave., Mount Vernon, N.Y.

HOW TO MAKE OPENINGS IN FLEXICORE DECKS—Describes step-by-step procedure for cutting openings of 1 in. or less in a Flexicore slab with a power or star drill, and 1- to 6-in. holes and over with a core drill or hammer and chisel. The manual sums up everything that need be known about framed or cut openings in Flexicore decks.—The Flexicore Co., Inc., 1932 E. Monument Ave., Dayton 1, Ohio.

TRUCO BLADES AND SAWS—Product information folder and price list. Describes company's line of masonry cutting equipment, including abrasive and diamond blades, heavy-duty masonry saws, concrete cutting saws, masonry and stone cutting saws.—Truco Masonry Drilling Division, Wheel Trueing Tool Co., 3200 West Davison, Detroit 38, Mich.

MODEL M-100 COMPRESSION AND FLEXURE MACHINE (M-100)—Describes unit designed specifically for testing small specimens such as 2 x 2-in. cubes, 3 x 6-in. and 2.8 x 5.6-in. cylinders, and concrete pipe cores in compression and soil cement beams

in flexure. Loading capacity, 60,000 lb; weighs 240 lb completely equipped.—Forney's Inc., Tester Division, P.O. Box 310, New Castle, Pa.

PSI CALCULATOR—Forney's Inc. has revised its psi calculator for concrete products so that it now includes instant conversion data from total load to psi on 17 standard test specimens and masonry units ranging from 2 x 2-in. cubes and 3 x 6-in. cylinders to 12 x 16-in. and 12 x 18-in. masonry units. —Forney's Inc., Tester Division, P.O. Box 310, New Castle, Pa.

CURRENT PROJECTS OF THE AMERICAN STANDARDS ASSOCIATION—A total of 425 American Standards Association projects are described in this 52-page booklet. In addition to listing the projects under ASA's 19 standards categories, the booklet describes the scope of each project, provides an index, and lists the sponsors. Where the project is handled by a sectional committee operating under ASA auspices, the officers of the committee are listed. A short preface describes the benefits of standards and how standardization is carried out under ASA procedures. Price per copy is $1.50—American Standards Association, Dept. PR 94, 70 E. 45th St., New York 17, N.Y.

SOLVING TUNNEL CONCRETING PROBLEMS (Bulletin MBR-P8)—Highway, railway, and water tunnels and their construction techniques are illustrated and described in this 28-page Master Builders Co. bulletin. Case histories on 12 major tunneling projects tell how Pozzolith was used to help solve concreting problems.—The Master Builders Co., Cleveland 3, Ohio

SEEDED EMERI-EPOX (Bulletin SE-1)—Skid-proof, slip-proof surfacing application utilizing emery aggregate and epoxy resins is described in 2-page illustrated bulletin. Discusses properties of Seeded Emeri-Epox, provides instruction for mixing and applying, and suggests typical applications.—O. S. Tyson and Co., Inc., 230 Park Ave., New York 17, N.Y.

HONEYWELL SCIENTIFIC AND TEST INSTRUMENTS CATALOG (G-10)—Condensed, 48-page catalog of Honeywell instruments for scientific measurement, recording, and testing. Gives brief description, typical illustration, salient specifications, and general information for each family of instruments.—Minneapolis-Honeywell Regulator Co., Station M-321, Wayne and Windrim Ave., Philadelphia 44, Pa.

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THE CONSTRUCTION WORKER IN THE UNITED STATES—34-page report on earnings, training, and working conditions of the construction workers in the United States.—United States Department of Labor, Office of the Secretary, Washington, D.C.

CT-710 CONCRETE TESTER—Bulletin on Soiltest's portable, 250,000-lb concrete testing machine. Gives complete specifications on the unit and information on accessory equipment for use with the concrete tester—Soiltest, Inc., 4711 W. North Ave., Chicago 39, Ill.

EVEREADY CONCRETE SAWS AND BLADES—Describes uses of concrete saws; includes specifications and lists special features of the 18-, 30-, and 36-hp models.—Eveready Briksaw Co., Department 585, 1104 Union Ave., Kansas City 1, Mo.

MATERIALS EVALUATION FACILITIES (Bulltin 5902)—Bulletin describes United States Testing Co.'s Materials Evaluation Division's extensive facilities and services for analysis, development, research, and inspection of materials and products. Among the services offered are metallurgical studies, metals chemistry, plastics evaluation, and physical testing.—United States Testing Co., 1415 Park Ave., Hoboken, N.J.

FURNANE FOOD PLANT FLOORS (Bulletin 3-2)—Up-dated bulletin describes Furnane food plant floors. Cites successful installations in dairies, packing houses, bottling plants, canneries and other food processing plants across the country. Contains a materials estimating table and lists resistances.—Atlas Mineral Products Company, Mertztown, Pa.

CLIPPER CONCRETE SAW CATALOG—Illustrated, 4-page price list and catalog contains information on Clipper concrete saws and blades. Diamond and reinforced abrasive blades are covered as well as hot pour and cold applied joint sealers for every sealing application.—Clipper Mfg. Co., Suite 185, Kansas City 8, Mo.

POWER TOOL CATALOG—Syntron announces publication of a 4-page catalog section on portable construction tools. The section includes specifications, data, and illustrations of the line of self-contained electric hammers and hammer drills, featuring automatic drill bit rotation. Also covers self-contained gasoline hammer paving breakers, rock drills, concrete vibrators, and vibrating floats.—Syntron Co., 1471 Lexington Ave., Homer City, Pa.

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